

01 SOLID FUELS

Sources, winning, properties

13/01305 Coal and char properties in high temperature entrained flow gasification

Tremel, A. *et al. Energy*, 2012, 45, (1), 176–182.

With the objective to measure coal conversion at realistic operation conditions the pressurized high temperature entrained flow reactor (PiTER) is developed. The pyrolysis of Rhenish lignite is studied at temperatures up to 1600 °C and pressures up to 2.5 MPa. At longer residence time (above 1.5 s) volatile yield is 68 wt% and independent of temperature and pressure. Char samples are extracted from the hot reaction zone and their reactivity is analysed by weight loss in thermogravimetric analysis experiments at defined conditions. Furthermore, specific char surface area is measured. At 1200 °C the intrinsic reactivity of char decreases by a factor of almost 7 from 0.5 s to 2 s residence time, but surface area (approximately 500 m²/g) is hardly affected. At 1400 °C and 1600 °C, the intrinsic reactivity also decreases, but simultaneously the surface area is reduced to below 300 m²/g. The difference in deactivation can only be explained by two different mechanisms: (i) experiments at 1200 °C are below the ash fusion temperature and graphitization at the char surface may lead to a reorganization of carbon atoms; (ii) above the ash fusion temperature, the melting of mineral matter additionally blocks the micropore structure and results in a loss of specific surface area.

13/01306 Effect of the anthracite ratio of blended coals on the combustion and NO_x emission characteristics of a retrofitted down-fired 660-MW_e utility boiler

Liu, G. *et al. Applied Energy*, 2012, 95, 196–201.

Industrial experiments were performed for a retrofitted 660-MW_e full-scale arch-fired boiler. The ignition position of the primary air/fuel mixture flow, furnace temperature and flue gas component after the air heater were measured with different anthracite ratios at loads of 660- and 380-MW_e. As the ratio of anthracite increased, the gas temperature decreased in the fuel-burning zones of the C4 and C6 burners, indicating a farther ignition position of the primary fuel/air flow under the arches, the gas temperature of the lower furnace decreased while that of the upper furnace increased, NO_x emissions decreased while both the exhaust gas temperature and carbon content in fly ash increased, and the boiler efficiency decreased. At the rated load, an anthracite ratio of 35% was optimal for economic efficiency. At low load, the negative gas pressure fluctuated remarkably, which led to unstable combustion in the furnace. To ensure safe and stable operation of the boiler, a mass ratio of anthracite of 25% is advisable.

Preparation

13/01307 Analysis of the use of waste heat obtained from coal-fired units in organic Rankine cycles and for brown coal drying

Łukowicz, H. and Kochaniewicz, A. *Energy*, 2012, 45, (1), 203–212.

The ever-increasing restrictions on greenhouse gas emissions have created a need for new energy technologies. One way to meet these new requirements is to optimize the efficiency of power units. This paper presents two energy technologies that, if used, will increase the efficiency of electricity generation. One of the most effective ways to improve the efficiency of brown coal-fired units is by drying the coal that is fed into the boiler. Here, the authors describe a technology that uses the waste heat obtained from exhaust gases. This paper also presents an analysis of the feasibility of and potential for using waste heat obtained from exhaust gases to feed organic Rankine cycles (ORCs). Several low-temperature working fluids were considered, which were selected based on properties that were best suited for these types of cycles. The impact of these working fluids on the efficiency and capacity of the ORC was also examined. The calculations for ORCs fed with waste heat obtained from exhaust gases from hard coal and brown coal-fired boilers were compared.

13/01308 Deep-staged, oxygen enriched combustion of coal

Daoud, S. S. *et al. Fuel*, 2012, 101, 187–196.

Oxygen enriched combustion of coal under different oxidant concentrations and staging levels has been performed in a 20 kW down fired pilot scale combustion test facility. The introduction of oxygen resulted

in additional reduction of NO emissions as compared to simple air staged configuration. In comparison to air staged combustion, oxygen enriched air staged combustion at the 31% level of staging resulted in approximately 7%, 20% and 35% NO reduction for 28%, 30% and 35% overall oxygen concentration, respectively. Experimental evidence has also indicated that oxygen enrichment does appear to reduce NO levels along with improvement of carbon burnouts. The provision of oxygen has also resulted in operation of the test facility under lowered stoichiometric ratios. The advantages attributable to oxygen enriched combustion also included enrichment of CO₂ concentration in the flue gas to reduce the cost of CO₂ scrubbing and capture. The present work provides data associated to oxygen enriched combustion technology, which can be considered a compromise between conventional air-firing combustion and the emerging oxy-fuel combustion systems.

13/01309 Generation of ultra-clean fuel from Victorian brown coal – synchrotron XANES study on the evolution of sulphur in Victorian brown coal upon hydrothermal upgrading treatment and thermal pyrolysis

Wijaya, N. and Zhang, L. *Fuel*, 2012, 99, 217–225.

This paper reported the speciation of sulfur in two parent Victorian brown coals and their upgraded derivatives through the use of direct, non-destructive synchrotron-based S K-edge XANES. Victorian brown coal is the single largest source for power generation in Victoria, Australia. To date little has been known about its sulfur speciation. The results here demonstrated the predominance of organosulfur in the forms of thiophene and mono-/poly-sulfide in Victorian brown coals, irrespective of coal mining location and particle size. The sulfidic sulfur in the raw coal was readily cleaved and released as gas upon hydrothermal leaching in citric acid at the temperatures up to 200 °C. The use of concentrated 5 M nitric acid for acid leaching caused the oxidation of a portion of sulfide and thiophene into organic sulfate which bears an XANES position between inorganic sulfate and sulfone. Thermal pyrolysis is more effective in reducing sulfur in char, resulting in an overall sulfur content as low as 0.1 wt% for the char produced at 800 °C. This is due to the rapid decomposition of organic sulfide commencing at 400 °C. The mobilization rate of thiophene associated with aromatic carbon varied greatly with coal type. For the sulfur released upon thermal pyrolysis, a portion of it was also captured by inherent alkali and alkaline earth metals forming sulfate particularly in the 800 °C char. A prior acid washing of coal favoured eliminating the formation of inorganic sulfate in the resulting char sample. However, the remaining sulfur in the coal was evolved to distinct structure that has a rather stronger resonant scattering, or in a formation of acid-insoluble sulfate caused by the oxidation/reformation of organic matrix.

13/01310 Hydrogenation process of the tar obtained from the pyrolysis [pyrolysis] of brown coal

Kusy, J. *et al. Fuel*, 2012, 101, 38–44.

Coal could be a potential substitute for crude oil as a raw material for the production of liquid fuels. The main objective of the transformation processes from coal to liquid fuels is the production of diesel and petrol. In the European Union there are several activities aimed at the liquefaction of coal. The EUROCOAL organization confirmed coal to liquid (CTL) associated with carbon dioxide capture and storage (CCS) as the best use of European coals. The brown coal research institute JSC, within the framework of research projects, is also interested in the technological resolution of CTL techniques. In the paper, research is aimed at the possible use of various Czech coals for those purposes. Several types of Czech coal from various mines were analysed for the basic technological characteristics and pyrolysed under specific conditions. The products obtained (solid, liquid and gaseous) were analysed. The liquid product, brown coal tar, was consequently hydrogenized in the reactor at a temperature of 300 °C under a pressure from 1 to 30 bar with the presence of a cobalt–molybdenum hydrogenation catalyst. Hydrogenation products were analysed by GC–MS chromatography and results were compared to the input tar.

13/01311 Investigation of technical and economic aspects of pre-dried lignite utilisation in a modern lignite power plant towards zero CO₂ emissions

Agraniotis, M. *et al. Energy*, 2012, 45, (1), 134–141.

The pre-drying technology is expected to play an important role in the next generation of brown coal power plants. The integration of the fluidized bed drying system with internal heat utilization (WTA technology) is estimated to bring an efficiency increase of up to six percentage points in future brown coal power plants compared to the current state of the art. Furthermore, brown coal pre-drying is considered as an indispensable part in future oxy-fuel brown coal fired boilers. In the present work the potential utilization of brown coal pre-drying is evaluated based on a realistic reference case scenario. Thermal cycle calculations and economic feasibility studies are carried out for a modern Greek power plant, taken as reference case and for two dry lignite firing cases. In the first co-firing scenario investigated a co-firing share of dry lignite to a thermal share of 25% is regarded.

Furthermore, the configuration of a brown coal boiler fired 100% with pre-dried lignite is examined. For all cases, the main economic parameters are calculated including investment costs, cost of electricity, payback period, return on investment. The effect of the CO₂ allowances price on the economic feasibility of the considered scenarios is also evaluated.

13/01312 Performance of a hybrid hydrogen–gasoline engine under various operating conditions

Ji, C. *et al. Applied Energy*, 2012, 97, 584–589.

This paper proposed a new combustion strategy for the spark-ignited (SI) engines. A gasoline engine was converted into a hybrid hydrogen–gasoline engine (HHGE) by adding a hydrogen injection system and a hybrid electronic control unit. Different from the conventional gasoline and hydrogen-enriched gasoline engines, the HHGE is fuelled with the pure hydrogen at cold start to produce almost zero emissions, with the hydrogen–gasoline blends at idle and part loads to further improve thermal efficiency and reduce emissions, and with the pure gasoline to ensure the engine power output at high loads. Because the HHGE is fuelled with the pure gasoline at high loads and speeds, experiments are only conducted at cold start, idle and part load conditions. Since lean combustion avails the further improvement of the engine performance, the HHGE was fuelled with the lean mixtures in all tests. The experimental results showed that the hybrid hydrogen–gasoline engine was started successfully with the pure hydrogen, which produced 94.7% and 99.5% reductions in HC and CO emissions within 100 s from the onset of the cold start, compared with the original gasoline engine. At an excess air ratio of 1.37 and idle conditions, indicated thermal efficiency of the 3% hydrogen-blended gasoline engine was 46.3% higher than that of the original engine. Moreover, the engine cyclic variation was eased, combustion duration was shortened and HC, CO and NO_x emissions were effectively reduced for the hybrid hydrogen–gasoline engines.

13/01313 Pyrolysis and combustion characteristics of coals in oxyfuel combustion

Wang, C. *et al. Applied Energy*, 2012, 97, 264–273.

Oxyfuel combustion technology is one of the near-zero emission clean coal technologies, which can realize the large-scale CO₂ capture, low NO_x emission, and easier removing of SO₂. This paper describes the characteristics of pyrolysis, gasification and combustion of coals and chars in oxyfuel combustion applying the non-isothermal thermogravimetric analysis. Experimental results show that the pyrolysis reactivity is highly similar in N₂ and CO₂ at low temperature. The mass loss rate of experimental coals in CO₂ increases significantly at around 810 °C. In comparison to the conventional combustion, thermogravimetric curves of coal and char combustion in O₂/CO₂ tend towards higher temperature zone. Sample mass, particle size and heating rate all have considerable effects on the heat and mass transport process, which influences the whole combustion process of coal particles in oxyfuel conditions. Char reactivity prepared in CO₂ is almost equivalent to that prepared in N₂. The results of kinetics analysis indicate that compensation effect exists between apparent activation energy and pre-exponential factor in different oxygen concentrations during both coal and char combustion.

13/01314 Semi-technical underground coal gasification (UCG) using the shaft method in experimental mine 'Barbara'

Wiatowski, M. *et al. Fuel*, 2012, 99, 170–179.

The underground coal gasification (UCG) trial was carried out at the experimental mine 'Barbara' within the RFCS Project HUGE (2007–2010). The georeactor was placed in the coal seam 310 at the depth of 30 m. During the period of 15 days about 22 tons of hard coal was gasified with the average consumption rate of 62 kg/h. The total volume of 71,764 N m³ of dry gas was produced. The gasified media applied were oxygen, air and water. The average heating value of product gas and thermal power generated in a flare were 3.8 MJ/N m³ and 211 kW, respectively. The average H₂ and CO contents in product gas were 14.2 vol.% and 13.4 vol.%, respectively. The calculated gasification efficiency was about 56%. The experiment revealed that gasification in thin, shallow-buried coal seams can cause some operational problems, since under such geological conditions high risk of gas leakages exists. The gas leakages strongly affect not only the overall process efficiency but can also cause toxic hazards near the UCG test site. The post-burn area venting was necessary for the period of 40 days after the installation shutdown. After this time, the reactor reached its initial thermal conditions.

13/01315 Thermal performance prediction of a solar hybrid gas turbine

Barigozzi, G. *et al. Solar Energy*, 2012, 86, (7), 2116–2127.

The present work focuses on a modelling procedure to simulate the operation of a solar hybrid gas turbine. The method is applied to a power generation system including an heliostat field, a receiver and a 36 MW commercial gas turbine. Heat is provided by concentrated solar

power and integrated by fossil fuel. A detailed modelling of the gas turbine is proposed to predict the performance of commercial gas turbine models in actual operating conditions. Advanced software tools were combined to predict design and off-design performance of the whole system: TRNSYS[®] was used to model the solar field and the receiver while the gas turbine simulation was performed by means of Thermoflex[®]. A detailed comparison between the solarized and the conventional gas turbine is reported, taking into account gas turbine electric power, efficiency and shaft speed. All thermodynamic parameters such pressure ratio, air flow and fuel consumption were compared. The main advantage of solarization is the fossil fuel saving, but it is balanced by a relevant penalty in power output and efficiency.

Transport, storage

13/01316 Internal, external and location factors influencing cofiring of biomass with coal in the U.S. northern region

Aguilar, F. X. *et al. Energy Economics*, 2012, 34, (6), 1790–1798.

The use of biomass as a source of energy has been identified as a viable option to diminish reliance on fossil fuels. The authors parameterized the effect of selected internal (e.g. coal-fire presence), external (e.g. price and renewable energy mandates) and location (e.g. biomass availability, infrastructure) variables on the likelihood of using biomass in cofiring with coal by building a two-stage econometric model. The first stage controlled for factors driving the spatial location of coal power plants and the second stage concentrated on factors influencing cofiring. The empirical model was applied in the northeast quadrant of the USA where the unit of observation was an individual county. Results of this model stress the significant effect of existing flexible coal feeding systems that permit the incorporation of biomass, transportation infrastructure and biomass availability (woody biomass in particular in the form of residues from the wood products industry). State-level renewable energy portfolio standards showed no statistically significant effect on the adoption of cofiring biomass with coal. Further developments of biomass cofiring in the US northern region are most likely to take place in the Great Lakes region.

Economics, business, marketing, policy

13/01317 Bio-coal, torrefied lignocellulosic resources – key properties for its use in co-firing with fossil coal – their status

Agar, D. and Wihersaari, M. *Biomass and Bioenergy*, 2012, 44, 107–111. Bio-coal has received generous amounts of media attention because it potentially allows greater biomass co-firing rates and net CO₂ emission reductions in pulverized-coal power plants. However, little scientific research has been published on the feasibility of full-scale commercial production of bio-coal. Despite this, several companies and research organizations worldwide have been developing patented bio-coal technologies. Are the expectations of bio-coal realistic and are they based on accepted scientific data? This paper examines strictly peer-reviewed scientific publications in order to find an answer. The findings to date on three key properties of torrefied biomass are presented and reviewed. These properties are: the mass and energy balance of torrefaction, the friability of the product and the equilibrium moisture content of torrefied biomass. It is these properties that will have a major influence on the feasibility of bio-coal production regardless of reactor technology employed in production. From recent results it can be seen that high-energy yields on studied materials are achieved at the expense of other key properties; heating value increase, grindability and equilibrium moisture content. These trade-offs are determined by the physical nature of the materials themselves. That large-scale bio-coal production would achieve more commercially advantageous results than these, should not be assumed. The results can be used to realistically model bio-coal production scenarios in terms of economics and greenhouse gas emission balance.

13/01318 DEA environmental assessment of coal fired power plants: methodological comparison between radial and non-radial models

Sueyoshi, T. and Goto, M. *Energy Economics*, 2012, 34, (6), 1854–1863. This study discusses how to apply data environment analysis (DEA) for environmental assessment. A unique feature of DEA environmental assessment is that it classifies outputs into desirable (good) and undesirable (bad) outputs because many firms often produce not only desirable outputs but also undesirable outputs as a result of their economic activities. A methodological difficulty of DEA applications is

how to combine operational performance on desirable outputs and environmental performance on undesirable outputs in a unified treatment. Although previous DEA environmental studies have utilized mainly radial models and their extensions, this study uses a non-radial DEA model for the output unification because the non-radial model can unify the two types of outputs more easily than the radial models. This study incorporates three types of output unification in DEA environmental assessment. The first unification considers both an increase and a decrease in an input vector along with a decrease in the direction vector of undesirable outputs. This type of unification measures 'unified efficiency'. The second unification considers a decrease in an input vector along with a decrease in the vector of undesirable outputs. This type of unification is referred to as 'natural disposability' and measures 'unified efficiency under natural disposability'. The third unification considers an increase in an input vector but a decrease in the vector of undesirable outputs. This type of unification is referred to as 'managerial disposability' and measures 'unified efficiency under managerial disposability'. All the unifications increase the vector of desirable outputs. Using the output unification under natural and managerial disposability, this study examines methodological strengths and drawbacks of the proposed non-radial approach. Moreover, using a data set on US coal-fired power plants, the authors compare methodological strengths and drawbacks of radial and non-radial models for DEA environmental assessments. The methodological comparison is important in guiding a large energy issue because policy implications depend upon a methodology(s) used for an empirical study.

13/01319 Environmental impact and cost analysis of coal versus nuclear power: the U.S. case

Vujić, J. *et al. Energy*, 2012, 45, (1), 31–42.

Both coal and nuclear power plants are likely to remain a crucial source of electricity in any conceivable future, representing the base-load electricity sources. It is predicted that coal use in the world will continue to increase having in mind that it is cheap and abundant. It is also predicted that nuclear power will continue to expand in Asia (China, India, Russia). In the USA, both coal and nuclear industry is in a stand-by position, waiting for the new regulatory rules on hazardous emissions and safety to be decided upon. This analysis showed that nuclear power industry in the USA has been over-regulated, while the coal-burning power industry has been under-regulated. Since the start of civilian nuclear power program in the USA more than 60 years ago, no worker or an individual from public died due to radioactive emissions from nuclear power plants (NPPs), while hazardous emissions from coal-burning plants contribute per year, based on US Environmental Protection Agency (EPA) data, to up to 17,000 of premature deaths. There is also a huge difference in the amount and volume of produced waste: millions of tonnes per year for a coal-burning plant and less than 30 tonnes for a nuclear plant of the same size. The EPA is finalizing a set of new rules that will considerably reduce hazardous emissions from coal-fired plants. While the various industry groups are warning that new regulations will cost utilities up to \$129 billion, force them to retire one-fifth of coal capacity, increase cost of electricity production, cause rolling blackouts and reduce the size of the workforce, the environmental groups praise the EPA work, and point out that the new rules will have large public health and environment benefits, and that industry groups are exaggerating the cost. It is to be seen in the near future which of these two opposing views will prevail. The US Blue Ribbon Commission has also finalized recommendations regarding the long-term US policy toward spent nuclear fuel management, suggesting prompt efforts to develop one or more repositories, to dedicate sufficient funding for that effort, to solve the problem of spent fuel transportations, to have a single agency that will be in charge of spent fuel management, to develop good international collaboration and to continue to develop advanced nuclear technology. These are the necessary steps in assuring sustainability of nuclear energy in the USA. On the other hand, after the Fukushima accident, the US Nuclear Regulatory Commission approved enhancement to emergency preparedness regulations governing commercial nuclear energy facilities, requiring reassessment of the seismic risks at the facilities, and added requirements for efficient plans to 'manage the effects of aging' in nuclear facilities. Emphasis on risk assessment, safety and security of nuclear power plants, an increase in the cost of construction materials, concerns with the extension of life of the existing NPPs, caused the cost of the new power plant construction to considerably increase. Regardless of the recent development, longer-term challenges remain for nuclear industry in the areas of spent fuel disposition, proliferation of nuclear technologies and materials, fuel resource management and fuel cycle economics. The coal-burning industry is also facing taxes for carbon capture and sequestrations as well as for the cost of hazardous pollutants reduction. If carbon-capture and sequestration tax is added, the leveled costs of coal and nuclear electricity production become comparable. The degree to which both nuclear and coal power could sustainably meet long-term energy needs will depend on the supported development of

advanced technologies for hazardous emission reduction, for spent fuel management and fuel cycle options, together with sound national and international policy and regulation implementations.

13/01320 Impact of wind power on generation economy and emission from coal based thermal power plant

Porate, K. B. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 889–896.

The major chunk of power generation is based on coal-fuelled thermal power plant. Due to increasing demand of power there will be future crises of coal reservoirs and its costing. Apart from this, coal-based thermal power plant is the main source of environmental emissions like carbon dioxides (CO₂), sulfur dioxides (SO₂) and oxides of nitrogen (NO_x), which not only degrades the air quality but also is responsible for global warming, acid rain etc. This paper proposes a combined working of doubly fed induction generator (DFIG) with coal-based synchronous generator (SG) in the MATLAB environment. STATCOM is suggested at common coupling point to maintain voltage stability and also maintain the system in synchronism. Analysis has been made for environmental emissions, coal requirement and system economy for both the cases, when the total load supplied by only SG and with the combination. Emission analysis has been also made with the application of washed coal in SG. With the impact of DFIG energy generation from SG have been reduces which proportionally effects on coal requirement, generation cost and environmental emissions. Application of washed coal improves the performance of SG and also reduces the environmental emissions.

13/01321 Reserve reporting in the United States coal industry

Grubert, E. *Energy Policy*, 2012, 44, 174–184.

US energy policymaking can be better supported with accurate and consistent data on coal reserves, both in the public and private sectors. In particular, reserve data for coal and other energy resources should be directly comparable so that decision-makers can easily understand the relationship among available resources. Long-term policy and investment choices regarding energy security, the environment, and resource allocation depend on accurate information, but existing and easily available data on the magnitude of geologically, environmentally, economically, socially, and legally accessible coal reserves are of insufficient quality to guide such decisions. Even still, these data are often presented for use in policy and energy analysis. Currently, coal reserves are overstated relative to competitor energy resource reserves, in part because coal reporting standards have historically been more liberal and vague than standards for resources like natural gas. Overstating the marketable coal resource could lead to inefficient allocation of limited capital investment that can be difficult to reverse. US government bodies like the Energy Information Administration, US Geological Survey, Securities and Exchange Commission, and Bureau of Land Management can help correct deficiencies by clarifying standards and collecting data that are relevant for decision-makers, such as energy-based reserve information.

13/01322 Returns to scale and damages to scale on U.S. fossil fuel power plants: radial and non-radial approaches for DEA environmental assessment

Sueyoshi, T. and Goto, M. *Energy Economics*, 2012, 34, (6), 2240–2259.

This study proposes a new use of data envelopment analysis (DEA) for environmental assessment, paying attention to a methodological bias (i.e. different methods produce different results). DEA is analytically classified into radial and non-radial approaches. The radial approach determines the level of unified (operational and environmental) efficiency by measuring an inefficiency score. The score indicates the distance of a projection from an observed performance to an efficiency frontier. In contrast, the non-radial approach determines the level of unified efficiency by measuring a total amount of slacks because each slack indicates inefficiency. To avoid the methodological bias, this study considers the use of radial and non-radial approaches. This study considers a production process where all organizations produce not only desirable (good) but also undesirable (bad) outputs as a result of their business operations. To unify the two types of outputs, this study discusses the concept of disposability, which is separated into natural and managerial disposability. The natural disposability indicates negative adaptation to a regulation change on undesirable outputs. In contrast, the managerial disposability indicates corporate strategy by which a firm considers the regulation change as a new business opportunity. A firm attempts to improve its unified efficiency by utilizing new environmental technology and/or new management. This type of strategy indicates positive adaptation to the regulation change. Under the two disposability concepts, this study discusses how to measure returns to scale (RTS) under natural disposability and damages to scale (DTS) (corresponding to RTS on undesirable outputs) under managerial disposability. The two scale measures are analytically discussed by the proposed radial and non-radial approaches with strong complementary slackness conditions (SCSCs) or

without SCSCs. An illustrative example on US fossil fuel power plants indicates a policy implication that they need to introduce new technology for environmental protection. This study also discusses a necessity of examining a methodological bias in energy studies. Empirical findings identified in this study document the practicality of the proposed approaches to measure RTS/DTS.

13/01323 Why do electricity utilities cooperate with coal suppliers? A theoretical and empirical analysis from China
Zhao, X. *et al. Energy Policy*, 2012, 46, 520–529.

The asymmetry of Chinese coal and electricity pricing reforms leads to serious conflict between coal suppliers and electricity utilities. Electricity utilities experience significant losses as a result of conflict: severe coal price fluctuations, and uncertainty in the quantity and quality of coal supplies. This paper explores whether establishing cooperative relationships between coal suppliers and electricity utilities can resolve conflicts. The study begins with a discussion of the history of coal and electricity pricing reforms, and then conducts a theoretical analysis of relational contracting to provide a new perspective on the drivers behind the establishment of cooperative relationships between the two parties. Finally, the authors empirically investigate the role of cooperative relationships and the establishment of mine-mouth power plants on the performance of electricity utilities. The results show that relational contracting between electricity utilities and coal suppliers improves the market performance of electricity utilities; meanwhile, the transportation cost savings derived from mine-mouth power plants are of importance in improving the performance of electricity utilities.

Derived solid fuels

13/01324 Calcium-promoted catalytic activity of potassium carbonate for steam gasification of coal char: influences of calcium species

Jiang, M.-Q. *et al. Fuel*, 2012, 99, 64–71.

Experiments were carried out to investigate the K_2CO_3 -catalysed gasification performances for varying chars prepared from four coals with prior addition of calcium additive and without calcium additive. Three calcium species, $Ca(OH)_2$, $Ca(Ac)_2$ or $Ca(CH_3COO)_2$, and $CaCO_3$, were used in the study. Experiments were also conducted in an attempt to achieve the understanding of the effect of calcium additive on the potassium deactivation, as well as the interactive effect between potassium, calcium and char. It was found that each calcium additive acted as a deterrent to the potassium deactivation and thus promoted the catalytic gasification, and the magnitudes of promotion varied depending on coal and calcium species. $Ca(OH)_2$ and $Ca(Ac)_2$ were more effective to inhibit the potassium deactivation than $CaCO_3$. Furthermore, potassium together with calcium showed a mineral-unrelated synergy towards the char gasification. A bimetallic carbonate, $K_2Ca(CO_3)_2$, which formed even when the chars prepared from coal with either $Ca(OH)_2$ or $Ca(Ac)_2$ was subsequently mixed with K_2CO_3 , was likely to contribute to the synergistic effect.

13/01325 Characterization of the woody cutting waste briquettes containing absorbed glycerol

Raslaivičius, L. *et al. Biomass and Bioenergy*, 2012, 45, 144–151.

The aim of the present work was to evaluate waste-to-energy technology for the utilization of crude glycerol (84.5% purity) surplus, collected by the largest Lithuanian biodiesel plants. The research examined the use of glycerol and woody (timber) cutting waste (WCW) to produce fuel briquettes. Two ratios of glycerol mass share 10% and 20% per unit volume were proposed as a partial substitute for WCW in briquette production process, thus solving glycerol utilization problems present in Lithuania. Proposed volumes of additive are in strong agreement with EN 14961–1. Affirmative proportions for interfusion of input materials, durability rating of fuel briquettes, characterization of combustion regimes and emission characteristics were assessed based on their composition. The optimum fuel properties were demonstrated by WCW briquettes containing maximum 10% glycerol mass concentration. Combustion of such briquettes exposed low CO , SO_2 and NO_x emission levels, falling under requirements of LAND 43–2001. Further increase in glycerol share is not recommendable, in the larger part due to the decrease in physical–mechanical properties, but not from emission constraints.

13/01326 Coke-free direct formic acid solid oxide fuel cells operating at intermediate temperatures

Chen, Y. *et al. Journal of Power Sources*, 2012, 220, 147–152.

Formic acid is investigated as a fuel for solid oxide fuel cells (SOFCs) for the first time. Thermodynamic calculations demonstrate that carbon deposition is avoidable above 600 °C. The carbon deposition properties are also investigated experimentally by first treating a nickel

plus yttria-stabilized zirconia (Ni-YSZ) anode material in particle form under a formic acid-containing atmosphere for a limited time at 500–800 °C and then analysing the particles by O_2 -TPO. This analysis confirms that carbon deposition on Ni-YSZ is weak above 600 °C. The authors further treat half-cells composed of YSZ electrolyte and Ni-YSZ anode under formic acid-containing atmosphere at 600, 700 and 800 °C; the anodes maintain their original geometric shape and microstructure and show no obvious weight gain. It suggests that formic acid can be directly fed into SOFCs constructed with conventional nickel-based cermet anodes. I–V tests show that the cell delivers a promising peak power density of 571 mW cm^{-2} at 800 °C. In addition, the cells also show good performance stability. The results indicate that formic acid is highly promising as a direct fuel for SOFCs without the need for cell material modifications.

13/01327 Effect of miscanthus addition and different grinding processes on the quality of wood pellets

Lehmann, B. *et al. Biomass and Bioenergy*, 2012, 44, 150–159.

In this study the mechanical properties of wood–miscanthus mixpellets for domestic use were investigated. The influences of a proportion of miscanthus of up to 0.20 kg kg^{-1} to the quality of wood pellets were tested. Furthermore binder addition (0.02 kg kg^{-1} of potato starch) and two different grinding processes (impact comminution under dry conditions and shearing comminution under wet conditions) were tested to improve the pellet quality. According to existing quality standards physical properties for the produced pellets have been determined to evaluate the quality. The results showed that for producing standardized pellets with miscanthus proportion the addition of a binder is necessary in the case of impact comminution. When using a shearing comminution for the raw material preparation no more binder addition is necessary to fulfil the quality criteria even with a miscanthus proportion of 0.20 kg kg^{-1} . The shearing comminution leads to a highly fibrous material that can be more compacted in the press channels than normal shavings and furthermore these fibres have a high potential to create interlocking bonds. Another effect might be a successful mechano-chemical activation of binder substances like proteins in the raw materials through the wet preparation step.

13/01328 Textural properties of chars as determined by petrographic analysis: comparison between air-blown, oxygen-blown and oxygen-enriched gasification

Obolrien, B. O. *et al. Fuel*, 2012, 101, 16–22.

In this study, the textural properties of chars generated from a vitrinite, high ash coal in a fluidized bed gasifier under air-blown, oxygen-blown and oxygen-enriched conditions were determined by detailed petrographic analysis. The char samples were assessed in terms of their microscopic characteristics (reflectance properties, carbon rich forms (char types) and basic forms of visible minerals). The chars formed under oxygen-blown conditions exhibited the lowest in overall mean reflectance value and also possessed the lowest proportion of chars with reflectance values above 4% RoVr relative to those in the air-blown and oxygen-enriched samples. The oxygen-blown sample also possessed the lowest total carbon forms (53%) whereas the oxygen-enriched and air-blown chars had higher proportions of organic matter (58% and 60% respectively). Melted ‘slag’ minerals were more common in the oxygen-blown char, totalling 31%, compared with 24% in the other two samples. These results suggest that a greater degree of consumption of carbon took place under the oxygen-blown conditions, possibly with higher particle temperatures, and that under these conditions, the highly reflecting porous thin-walled chars would have been consumed first and fastest. This would have left the higher proportion of partially consumed chars and inertinites behind which, in turn, would have led to the occurrence of lower reflectance readings. These conditions also resulted in the presence of higher proportions of melted ‘slag’ minerals in the oxygen-blown sample. The oxygen-enriched and air-blown chars appear to have undergone reduced levels of carbon consumption and at lower particle temperatures relative to the oxygen-blown sample. Of these two samples, the air-blown sample had the lowest rate of consumption of all three conditions. This, in turn, implies that the temperatures operating under these conditions were the lowest of all. In summary, it would appear that the conditions under which the most rapid rates of consumption would occur, in decreasing order of reactivity and particle temperature, would be (i) oxygen-blown, (ii) oxygen-enriched and (iii) air-blown. These results have important implications for the future, namely, (i) to ensure the highest optimum efficiencies in future gasification processes by selecting the most appropriate gaseous environments and (ii) to prevent or minimize the occurrence of slagging in future gasification processes. This is specifically applicable to operations involving fluidized bed technologies and may well be of value in countries in which high ash coals will be the primary energy source in such technologies.

02 LIQUID FUELS

Sources, properties, recovery

13/01329 Aromaticity of five- and six-membered heterocycles present in crude oils – an electronic description for hydrotreatment processValencia, D. *et al. Fuel*, 2012, 100, 177–185.

The present work is focused on attempt to understand the importance of aromaticity in the elimination of N, O and S atoms from five-membered heterocycles and catalyst poisoning by basic nitrogen six-membered heterocyclic compounds in the hydrotreatment (HDT) process. Pyrrole, furan, thiophene and pyridine, and their fused benzene ring derivatives have been studied by means of density functional theory (DFT). Proton affinities (PAs) were calculated for all these compounds, geometrical modifications were observed during protonation. Five-membered aromatic compounds break planarity due to proton interaction of the heteroatom, while pyridine-type compounds do not. Aromatic stabilization energy (ASE) was calculated by homodesmotic chemical reactions for all heterocyclic compounds. The energetic trends for protonated and unprotonated compounds confirm the less reactivity of dibenzo-compounds in the HDT process and catalyst's poisoning by pyridine derivatives present in crude oils.

13/01330 Combined process schemes for upgrading of heavy petroleumCastañeda, L. C. *et al. Fuel*, 2012, 100, 110–127.

Key refinery technologies for upgrading of heavy oils feasible to be combined to increase yield and quality of upgraded oil are reviewed and analysed. Hydrogen addition and carbon rejection based technologies are described to establish their current situation for heavy oil and residue upgrading. Various integrations of upgrading processes were identified in the literature and others have been proposed, which include deasphalting, gasification, delayed coking, RFCC, ebullated-bed hydrocracking, slurry-phase hydrocracking and fixed-bed hydrotreating. The main advantages of the integrated process schemes were highlighted in terms of product yields, quality of products, elimination of low-value by-products and reduction of impurities.

13/01331 Kinetic model for hydrocracking of heavy oil in a CSTR involving short term catalyst deactivationMartínez, J. and Ancheyta, J. *Fuel*, 2012, 100, 193–199.

A five-lump model previously reported in the literature was used for the kinetic modelling of an atmospheric residue (312 °C+) hydrocracking. The model has 10 reaction rate coefficients, makes a distinction of different hydrocarbon groups based on boiling ranges, and includes the following lumps: unconverted vacuum residue (538 °C+), vacuum gas oil (VGO; 343–538 °C), middle distillates (204–343 °C), naphtha (IBP–204 °C), and gases. The kinetic study was carried out in a CSTBR at the following operating conditions: 380–420 °C, 100 kg/cm², 5000 std ft³ H₂/bbl of oil, and 0.5–1.25 ml_{feed}/ (ml_{cat}·h). Experiments were performed with a commercial size tetra lobular catalyst. The model also incorporates the effectiveness factor, and a time-dependent deactivation function for obtaining the intrinsic kinetic parameters. The hydrocracking of vacuum residue, VGO and middle distillates exhibited a higher selectivity toward the heavier lumps as temperature is increased. The predicted product composition is in good agreement with experimental values with an average absolute error less than 5%.

13/01332 Strontium isotope systematics of mixing groundwater and oil-field brine at Goose Lake in northeastern Montana, USA

Peterman, Z. E. *et al. Applied Geochemistry*, 2012, 27, (12), 2403–2408. Groundwater, surface water, and soil in the Goose Lake oil field in north-eastern Montana, USA have been affected by Cl[−]-rich oil-field brines during long-term petroleum production. Ong-oing multidisciplinary geochemical and geophysical studies have identified the degree and local extent of interaction between brine and groundwater. Fourteen samples representing groundwater, surface water, and brine were collected for Sr isotope analyses to evaluate the usefulness of ⁸⁷Sr/⁸⁶Sr in detecting small amounts of brine. Differences in Sr concentrations and ⁸⁷Sr/⁸⁶Sr are optimal at this site for the experiment. Strontium concentrations range from 0.13 to 36.9 mg/L, and corresponding ⁸⁷Sr/⁸⁶Sr values range from 0.71097 to 0.70828. The local brine has 168 mg/L Sr and a ⁸⁷Sr/⁸⁶Sr value of 0.70802. Mixing relationships are evident in the data set and illustrate the sensitivity of Sr in detecting small amounts of brine in groundwater. The location

of data points on a Sr isotope-concentration plot is readily explained by an evaporation-mixing model. The model is supported by the variation in concentrations of most of the other solutes.

13/01333 Technological progress and the availability of European oil and gas resources

Aguilera, R. F. and Ripple, R. D. *Applied Energy*, 2012, 96, 387–392. This paper estimates supply cost curves for conventional oil and gas in Europe. Oil and gas volumes are distributed across five categories that are based on production costs. The resulting supply figures are intended to be long term representations of how quantities vary with production costs. Both economic and physical measures are used since each provides practical information with respect to the concerns some energy commentators have expressed about oil and gas scarcity in the near future. Supply cost curves incorporating the effect of annual technological advancement (i.e. productivity gains) on production costs to the year 2030 are also estimated. On the quantity side, the curves include volumes from geological provinces not previously assessed. Results indicate that conventional oil and gas in Europe is abundant and can likely be produced at costs below current and projected market oil and gas prices.

Transport, refining, quality, storage

13/01334 Co-processing of standard gas oil and biocrude oil to hydrocarbon fuelsAglevor, F. A. *et al. Biomass and Bioenergy*, 2012, 45, 130–137.

The major obstacle in thermochemical biomass conversion to hydrocarbon fuels using pyrolysis has been the high oxygen content and the poor stability of the product oils, which cause them to solidify during secondary processing. The authors have developed a fractional catalytic pyrolysis process to convert biomass feedstocks into a product termed 'biocrude oils' (stable biomass pyrolysis oils) which are distinct from unstable conventional pyrolysis oils. The biocrude oils are stable, low viscosity liquids that are storable at ambient conditions without any significant increases in viscosity; distillable at both atmospheric pressure and under vacuum without char or solid formation. About 15 wt% biocrude oils containing 20–25% oxygen were blended with 85 wt% standard gas oil and co-cracked in an advanced catalyst evaluation (ACETM) unit using fluid catalytic cracking (FCC) catalysts to produce hydrocarbon fuels that contain negligible amount of oxygen. For the same conversion of 70% for both the standard gas oil and the biocrude oil/gas oil blends, the product gasoline yield was 44 wt%, light cycle oil (LCO) 17 wt%, heavy cycle oil (HCO) 13 wt%, and liquefied petroleum gas (LPG) 16 wt%. However, the coke yield for the standard gas oil was 7.06 wt% compared to 6.64–6.81 wt% for the blends. There appeared to be hydrogen transfer from the cracking of the standard gas oil to the biocrude oil which subsequently eliminated the oxygen in the fuel without external hydrogen addition. The authors have demonstrated for the first time that biomass pyrolysis oils can be successfully converted into hydrocarbons without hydrogenation pretreatment.

13/01335 Efficacy of specific gravity as a tool for prediction of biodiesel–petroleum diesel blend ratioMoser, B. R. *Fuel*, 2012, 99, 254–261.

Prediction of volumetric biodiesel/petrodiesel blend ratio (V_{BD}) from specific gravity (SG) data was the subject of the current investigation. Fatty acid methyl esters obtained from soybean, palm and rapeseed oils along with chicken fat (SME-1, SME-2, PME, RME and CFME) were blended (0–20 vol.%) with three ultra-low sulfur (<15 ppm S) diesel (ULSD) fuels and SG at 15.6 °C was measured. Least-squares statistical regression on SG data from each of the biodiesel/ULSD blend sets revealed highly linear relationships ($R^2 > 0.991$) between SG and V_{BD} . Blends with the highest R^2 values from each of the ULSD fuels were used as model systems to develop predictive equations useful for calculation of V_{BD} from SG. The results indicated that accurate prediction of V_{BD} from SG was most effective when applied to blends prepared from the same fuel-types as the model systems used to develop the predictive equations.

13/01336 Heavy oil upgrading at moderate pressure using dispersed catalysts: effects of temperature, pressure and catalytic precursorOrtiz-Moreno, H. *et al. Fuel*, 2012, 100, 186–192.

A study of the influence of reaction parameters (reaction temperature, pressure and catalytic precursor) on the upgrading of Maya heavy oil under low pressure and moderate temperature under slurry conditions is presented. The behaviour of the purely thermal hydrotreating system was first characterized to have a basis for distinguishing the effect of incorporating a catalyst in further hydrotreatings. The distillation curves of liquid product were obtained by thermogravimetric analysis,

ASTM standards were used for evaluation of API gravity and content of asphaltenes and carbenes-carboids. The separated asphaltenes were analysed by X-ray diffraction and C^{13} nuclear magnetic resonance techniques. The effect of temperature, catalytic precursor and pressure (800 and 960 psi) of process were studied. The study of thermal hydrotreating showed that 390 and 400 °C were promising temperatures for catalytic hydroprocessing and increasing pressure approximately 100 psi promoted the improvement of light liquid fractions at the expense of the heavy and residua fractions. The use of catalytic precursors at 400 °C in concentrations of 330 ppm of Mo increased gasoline production without producing more solids but did not result in the improvement of the liquid yield in comparison to the homologous thermal hydrotreatment. The liquid yield was improved either hydrotreating at 390 or at 400 °C with 1000 ppm Mo as catalyst.

13/01337 Impact of dependent stochastic defect growth on system reliability of corroding pipelines

Zhou, W. *et al. International Journal of Pressure Vessels and Piping*, 2012, 96–97, 68–77.

This paper presents a methodology to evaluate the time-dependent system reliability of corroding pipeline segment containing multiple spatially-correlated active corrosion defects. The pipeline segment is modelled as a series system considering three distinctive failure modes at a given corrosion defect. The defect depth growth is modelled using gamma distributed time-independent growth model and gamma process-based growth model; the spatial correlation between the depth growths of different defects is characterized using the copula function. Numerical examples are used to investigate the impact of the spatially dependent (or correlated) defect depth growth characteristics, the uncertainties in the initial defect sizes (i.e. depth and length) and the model error associated with the burst pressure model on the system failure probability.

13/01338 Lagrangian coupling two-phase flow model to simulate current-induced scour beneath marine pipelines

Zanganeh, M. *et al. Applied Ocean Research*, 2012, 38, 64–73.

This paper presents a Lagrangian coupling two-phase flow model for simulating scour processes beneath a marine pipeline with respect to the sediment and fluid phase interactions. Smoothed particle hydrodynamics (SPH) capability is employed to simulate sediment and fluid particles movement, respectively as the Newtonian and non-Newtonian fluids in the framework of two-phase flow modelling. The sub-particle scale (SPS) model also is closed to the fluid phase solver to account for the turbulence effects. The soft contact approach is incorporated in the sediment phase to simulate the interparticle collisions during the local scouring. Following to the Lagrangian coupling model development, the current-induced scour beneath a pipe at tunnel erosion and early stages of lee-wake erosion were explored and then compared with the experiments. The obtained results illustrated the efficiency of the proposed two-phase flow model to reproduce the scour profiles evolution up to the early stages of lee-wake erosion. Within the presented model, the parameters such as pressure field and non-dimensional sediment transport rate beneath the pipe were also estimated.

13/01339 Simulation and planning of a petroleum refinery based on carbon rejection processes

Aguiar, R. A. *et al. Fuel*, 2012, 100, 80–90.

A superstructure for the simulation of a typical petroleum refinery process scheme is developed in this work. The model consists of hydrotreating of naphtha, jet fuel, kerosene, light gas oil and FCC feed. It also includes catalytic reforming and catalytic cracking. For the processing of bottom-of-barrel the model considers delayed coking, visbreaking and gasification. The superstructure is capable to select those processes that will meet the products specifications. The processing units have operating variables which affect the product flow rates and properties. The objective function is to maximize the profitability of the entire refinery, optimizing the operating variables of the units and vacuum residue flow rate sent to each upgrading process. The best process scheme resulted that with the combination of delayed coking and gasification.

Economics, business, marketing, policy

13/01340 Cross dynamics of oil-stock interactions: a redundant wavelet analysis

Jammazi, R. *Energy*, 2012, 44, (1), 750–777.

The main aim of the present paper is to explore how the interactions between crude oil (CO) price changes and stock returns of five developed countries namely USA, Canada, Germany, Japan and UK, evolve simultaneously over time and frequency, in light of the

conflicting evidence provided by much of recent studies on the sign and the direction of this relationship. To this end, a more efficient wavelet tool was applied, namely Haar à trous wavelet transform that helped circumvent the problems of the standard regression techniques and proved its effectiveness in encircling the real data features. In order to provide more credible conclusions, the wavelet variance, correlation and cross-correlation were implemented. In general, the existing empirical works were expanded by providing more generalized and convincing results inherent to the stock-oil markets interactions which are usually reputed to be complicated. First, evidence was found that the wavelet variances of all the variables decrease with increasing scales. Second, from the analysis of the wavelet correlation, changes in CO and almost all the stock prices do not move together up to the intermediate scale, but since they abruptly shift their direction in unison. Third, results for the wavelet CCF at scales 2, 3 and/or 4 generally illustrated no transmission mechanism between CO and the stock market returns although the authors provided support for massive CO variations at these scales. In contrast, the CO-equity market relationships at higher scales become interconnected in a negative unidirectional pattern running from CO to stock market returns for only two oil importing countries but also Canada. For oil exporting countries, while highly transient (scale 1) positive/negative causalities flowing from TSX stock market to CO changes are detected, highly persistent (scale 6) positive causality running from FTSE to the CO changes are rather found. Finally, the implications of the study's results vary depending on the oil – stock market linkages' sensitivity to the degree of improvement in energy efficiency of a given country, the degree of oil shock persistence, and to whether a country is oil importer or exporter (among other suggested factors).

13/01341 Cross-country differences in the effects of oil shocks

Peersman, G. and Van Robays, I. *Energy Economics*, 2012, 34, (5), 1532–1547.

The authors compare the macroeconomic consequences of several types of oil shocks across a set of industrialized countries that are structurally very diverse with respect to the role of oil and other forms of energy in the economy. The results crucially depend on the underlying source of the oil price shift. When a rise in oil prices is caused by increased global economic activity or a rise in oil-specific demand, almost all countries experience respectively a temporary increase and transitory decline of real gross domestic product. The role of oil and other forms of energy cannot explain the differences in the effects of both shocks across countries. In contrast, this role is very important to explain asymmetries in the effects of exogenous oil supply shocks. Whereas net oil and energy-importing countries typically face a permanent fall in economic activity, the impact is insignificant or even positive in net energy-exporting countries. In addition, countries that improved their net energy-position the most over time, became less vulnerable to oil supply shocks relative to other countries.

13/01342 Feasibility study of hybrid diesel–PV power plants in the southern of Algeria: case study on AFRA power plant

Khelif, A. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 546–553.

Nowadays levelized electricity cost of diesel power plants in the southern of Algeria is relatively higher because of its low efficiency compared to other modern plants, high maintenance and operations costs and many other difficulties to feed with fossil fuel due to its arid area. This study investigates the feasibility of hybridization of AFRA diesel power plant with a photovoltaic (PV) system whereby the performances of each part have been simulated. In order to do so, the meteorological data of the selected plant location as well as its technical data are first collected. Then, an annual techno-economic analysis is applied to test the feasibility of such hybrid plant. The simulation results confirm that the hybrid configuration is truly feasible even though the levelized electricity cost is very sensible to fossil fired fuel cost.

13/01343 Fuel dilution and liquid fuel operational effects on ultra-high thermal intensity distributed combustor

Arghode, V. K. *et al. Applied Energy*, 2012, 95, 132–138.

Ultra-high thermal intensity colourless distributed combustion has been examined for methane and methane diluted with air, nitrogen or carbon dioxide gas and liquid fuel (ethanol) burning in air at a fixed thermal load. Fuel was diluted with inert gases and air to simulate the combustion of low heating value fuels with special focus on the emission of pollutants. Reverse cross-flow configuration has been investigated at very high thermal intensities in the range of 156–198 MW/m³ atm with specific focus on the exhaust emissions, and distribution of intermediate radical species emission and flowfield from within the combustor using novel but simplified geometry for easy transition to practical applications in ultra-high thermal intensity gas turbine engine applications. The ultra-high combustion intensity

demonstrated here is significantly higher than that used in current stationary gas turbine engines. Numerical simulations are also performed under non-reacting conditions to understand the effects of fuel injection in cross flow configuration for both undiluted and diluted fuel cases. Ultra low NO_x emissions are achieved for both the novel premixed (3ppm) and non-premixed (8ppm) mode using methane as fuel at equivalence ratio of 0.6. Carbon monoxide level of about 100ppm was obtained in both novel premixed and non-premixed modes of combustion at equivalence ratio of 0.6. Dilution of fuel significantly reduced NO emissions to 2 from 8ppm and slightly increased CO emissions in non-premixed mode at equivalence ratio of 0.6. Dilution of fuel suggested much lower OH* suggesting favourably mixed oxidizer prior to ignition that results in lower NO emissions. Liquid fuel (ethanol) was also examined and very low NO emission of about 6ppm was obtained in direct-injection mode and 2ppm in premixed–prevaporized mode at equivalence ratio of 0.6. CO emission of about 200ppm was observed in both the modes at equivalence ratio of 0.6.

13/01344 Modelling and analysis of oil import tariff and stockpile policies for coping with supply disruptions

Bai, Y. *et al. Applied Energy*, 2012, 97, 84–90.

The potential economic damages from oil supply disruptions could be suppressed by emergency preparedness and response measures. As two of the most feasible response measures, oil import tariff and strategic petroleum reserve (SPR) could alleviate short-run oil supply and demand imbalance situations. This study develops a two period model to explore China's optimal tariff rate and stockpiling size. The objective is to minimize potential social welfare loss and macroeconomic loss associated with supply disruptions, as well as the policy cost. In a representative numerical case, China's optimal tariff rate was found to be \$3.8/bbl and stockpiling size is 219.4 million barrels. Higher tariff rate and lower stockpiling size are recommended contrast with current tariff and stockpiling policy. Additionally, by examining the net benefit of policy during a disruption, this result shows that the optimal implementation of tariff–stockpiling policy benefits most rather than single tariff or stockpiling policy does.

13/01345 Modelling optimal production rate with contract effects for international oil development projects

Zhao, X. *et al. Energy*, 2012, 45, (1), 662–668.

Optimizing oil production rate is one of the main challenges in designing development plan of oilfield in international cooperation projects. This paper establishes an oil production rate optimization model to maximize economic benefits within constraints of geological conditions and technology factors as well as oil contracts. This analysis describes the effects of contract terms on parameters of inputs and outputs, quantifies the relationships among production rate and production time, production, investment and costs. The oil exploration and production (E&P) project is illustrated for example, in which the optimal production rate under its own geological conditions and contract terms is calculated. The results reflect that the contract terms exert a tremendous influence on optimal production rate, at which the production in plateau phase occurs on the boundary of sliding scales provided in the contract. Simultaneously, changes in oil prices do not affect the optimal production rate. This study is important for companies to negotiate some elastic terms in contracts and design reasonable development strategies for resource distribution.

13/01346 Oil market structure, network effects and the choice of currency for oil invoicing

Mileva, E. and Siegfried, N. *Energy Policy*, 2012, 44, 385–394.

Crude oil is a homogeneous good traded on specialized exchanges and quoted and invoiced predominantly in US dollars. Despite the strong case for the use of the US dollar as a vehicle currency in the oil trade, the authors provide an alternative view. They develop a simple network effects model to identify the conditions under which either a complete switch in the oil invoicing currency or parallel invoicing in different currencies is possible and economically sensible. They calibrate the model using low actual values for the transaction costs of using the euro and/or US dollars, as well as a proxy for information costs, which decline with the increase in the use of the new currency. The results show that there will be a switch to parallel invoicing in both currencies when two conditions are met: first, oil exporters expect that a certain minimum number of other oil exporters will also start using the new currency; and second, the information costs associated with quoting oil contracts in two currencies are low.

13/01347 Oil price movements and stock markets revisited: a case of sector stock price indexes in the G-7 countries

Lee, B.-J. *et al. Energy Economics*, 2012, 34, (5), 1284–1300.

Applying sector stock prices and oil prices in January 1991 to May 2009 from the G7 countries, the authors found that oil price shocks do not significantly impact the composite index in each country. However, stock price changes in Germany, the UK and the USA were found to

lead oil price changes. As for the interaction between oil price changes and sector stock price changes, they found short-run negative causal relationships: four of seven sector index returns were impacted by oil price changes in Germany, two in the USA and one in France. In particular, stock returns of information technology and consumer staples sectors were found to be impacted most by oil price shocks, followed by financial, utilities and transportation sectors. In terms of causality from sector stock price changes to oil price changes, the authors found stock price changes lead oil price changes in eight of nine sectors in Germany, most in the G7 countries followed by the UK, Italy, France, Canada and the USA. No such a causal relationship, however, is found for Japan. With respect to specific sectors, stock price changes in consumer staples and materials sectors were impacted most significantly by oil price changes followed by transportation, financial, energy, health care, industrials, utilities, information technology and telecommunication sectors with the exception of consumer discretionary sector. In addition, short term stock price changes are found to lead positively oil price changes.

13/01348 Oil shocks and their impact on energy related stocks in China

Broadstock, D. C. *et al. Energy Economics*, 2012, 34, (6), 1888–1895.

This paper contributes to the current literature by adopting time varying conditional correlation and asset pricing models to discover how the dynamics of international oil prices affect energy related stock returns in China. After conditioning for structural instability, the results show a much stronger relation following the 2008 financial crisis. The authors argue that this reflects the fact that investors in the Chinese stock market, especially for energy related stocks, are more sensitive to the shocks in international crude oil market.

13/01349 Rational habits in gasoline demand

Scott, K. R. *Energy Economics*, 2012, 34, (5), 1713–1723.

The dynamics of demand for energy goods such as gasoline are complicated by investment decisions and behavioural habits. Both types of complication can be captured by a habits model, in which past consumption enters into an agent's current utility function. If the agent is forward-looking, or 'rational', then habits imply their consumption of the habit-forming good will be sensitive to their expectation of future market conditions, in particular future prices. This sensitivity implies, in turn, that traditional measures of price elasticity will underproject consumers' responsiveness to policy interventions. This paper examines the implications of rational habits on gasoline demand. Using a simple model encompassing myopic and rational habits, the author demonstrates that an agent with rational habits will respond to anticipated future price changes and react more strongly to permanent than to temporary price changes, with this distinction increasing in the strength of the habit. The author then estimates several habits models using panel data on US states for the years 1989 through 2008. The author's preferred specification yields evidence of rational habits, and moreover finds consumers to be twice as responsive to tax-driven price changes as to market-driven price changes. Taxes and other policies that operate through the gasoline price are a more powerful policy instrument than traditional price elasticity would lead us to believe.

13/01350 Reverse globalization: does high oil price volatility discourage international trade?

Chen, S.-S and Hsu, K.-W. *Energy Economics*, 2012, 34, (5), 1634–1643.

This paper examines whether higher oil price volatility causes a reversal in globalization. Using a large annual panel data set covering 84 countries all over the world from 1984 to 2008, the authors investigate the impacts of oil price fluctuations on international trade, namely exports and imports. They present strong and robust evidence that international trade flows will be lower when oil prices fluctuate significantly and therefore conclude that oil price volatility hurts globalization.

13/01351 Scenario of the emerging shift from gasoline to LPG fuelled cars in Ghana: a case study in Ho Municipality, Volta Region

Biscoff, R. *et al. Energy Policy*, 2012, 44, 354–361.

The use of liquid petroleum gas (LPG) as automotive fuel is on the increase worldwide. In developing countries such as Ghana, the rudimentary way of operating LPG cars is of a national concern since there is no clear-cut framework within which they function. This paper presents a scenario of development from conversion of gasoline to LPG fuelling system in cars in Ho, Ghana. Data were collected through survey (100 questionnaires), in-depth interviews (two), focus group discussions (three) and direct observations. The result shows LPG conversion is carried out by the local informally trained mechanics especially for taxis because of its low consumption resulting in more profit. Conversion takes 1–2 days with an average estimated cost of 450 Ghanaian cedis (\$300). The LPG policy in Ghana focuses on domestic purposes hence the fuel being heavily subsidized. Challenges being faced by the autogas market in Ghana include: no clear cut

policy, low number of refuelling stations, lack of standard conversion and installation kits and unprofessional LPG installers. In order for government to benefit from LPG as automotive fuel, coherent autogas policy should be formulated ensuring the availability of the LPG with price affordability as in the case of gasoline and diesel.

13/01352 Sustainability assessment of bioethanol and petroleum fuel production in Japan based on energy analysis

Liu, J. *et al. Energy Policy*, 2012, 44, 23–33.

To promote the reduction of greenhouse gas emissions, research and development of bioethanol technologies are encouraged in Japan and a plan to utilize untillable fields to develop rice for bioethanol production as a substitute for petroleum fuel is being devised. This study applies energy methods to compare the sustainability of petroleum fuel production and two Japanese rice-to-ethanol production scenarios: (a) ethanol from rice grain, while straw and chaff are burned as energy and (b) ethanol from rice + straw + chaff. The major energy indices, energy yield ratio (EYR), environmental loading ratio (ELR), energy investment ratio (EIR), energy sustainability index (ESI), environmental impacts ratio (EVR) and system transformity (Tr), are analysed to assess the production processes. The results show that (1) petroleum fuel production presents higher ELR, EIR, EVR and lower EYR, ESI, Tr than rice-to-ethanol production, indicating rice-to-ethanol production makes sense for reduction of greenhouse gases (GHG); (2) scenario (a) performs similarly on major indicators (EYR, ESI, ELR, EIR and EVR) to scenario (b), yet the system efficiency indicator (Tr) of scenario (a, 7.572×10^5 semj/J) is much higher than (b, 4.573×10^5 semj/J), and therefore (b) is a better alternative for policy decisions; (3) both petroleum fuel production and rice-to-ethanol processes are mainly driven by purchased resources and are unsustainable and non-renewable in the long run.

13/01353 Volatility transmission and volatility impulse response functions in crude oil markets

Jin, X. *et al. Energy Economics*, 2012, 34, (6), 2125–2134.

Using daily data from July 2005 to February 2011 for West Texas Intermediate (WTI), Dubai and Brent futures contracts, the authors employ a VAR-BEKK model to investigate crude oil markets integration on the second moment. They also quantify the size and persistence of these connections through the analysis of volatility impulse response functions (VIRF) for two historical shocks, namely the 2008 financial crisis and the BP *Deepwater Horizon* oil spill. It was observed that Brent and Dubai crude are highly responsive to market shocks, whereas WTI crude shows the least responsiveness of the three benchmarks, which creates questions about its predominance as a benchmark crude oil. Furthermore, the authors fit the density of the VIRF at different forecast horizons. These fitted distributions are asymmetric, showing that the probability of observing a large impact of a shock is lower while the probability of a relatively smaller impact is much higher. Finally, they simulate the VIRF for a given probability of a random shock. The VIRF shows that only a 'large' shock (derived from a smaller probability) will result in an increase in expected conditional volatilities. These results provide useful insights into the volatility transmission mechanism in crude oil markets and their associated risk estimation, and may have significant implications for various market participants and regulators.

Derived liquid fuels

13/01354 An investigation on characteristics of coal–water slurry prepared from the solid residue of plasma pyrolysis of coal

Chen, X. *et al. Energy Conversion and Management*, 2012, 62, 70–75. As massive amount of solid residue is produced from plasma pyrolysis of coal, reasonable use of such residue is significant in protecting environment and improving economic performance. This work is focusing on the fundamental research of the characteristics of coal–water slurry (CWS) prepared from the solid residue of plasma pyrolysis of coal. The effect of particle size, solid concentration, pH and temperature on the rheological properties of CWS is investigated. Shear-thinning behaviour of suspension has been observed depending on component content and operating conditions. Static stability is also investigated by sedimentation test. A more suitable cubic model for expressing the relation between viscosity and temperature is proposed.

13/01355 Catalytic conversion of carboxylic acids in bio-oil for liquid hydrocarbons production

Wang, S. *et al. Biomass and Bioenergy*, 2012, 45, 138–143.

Bio-oil must be upgraded to be suitable for use as a high-grade transport fuel. Crude bio-oil has a high content of carboxylic acids which can cause corrosion, and the high oxygen content of these acids also reduces the oil's heating value. In this paper, acetic acid and propanoic acid were chosen as the model carboxylic acids in bio-oil. Their behaviour in the production of liquid hydrocarbons during a catalytic conversion process was investigated in a micro-fixed bed reactor. The liquid organic phase from this catalytic conversion process mainly consisted of liquid hydrocarbons and phenol derivatives. Under the condition of low liquid hourly space velocity (LHSV), the liquid organic phase from acetic acid cracking had a selectivity of 22% for liquid hydrocarbons and a selectivity of 65% for phenol derivatives. The composition of the organic products changed considerably with the LHSV increasing to 3 h^{-1} . The selectivity for liquid hydrocarbons increased up to 52% while that for phenol derivatives decreased to 32%. Propanoic acid performed much better in producing liquid hydrocarbons than acetic acid. Its selectivity for liquid hydrocarbons was as high as 80% at $\text{LHSV} = 3 \text{ h}^{-1}$. A mechanism for this catalytic conversion process was proposed according to the analysis of the components in the liquid organic phases. The pathways of the main compounds formation in the liquid organic phases were proposed, and the reason why liquid hydrocarbons were more effectively produced when using propanoic acid rather than acetic acid was also successfully explained. In addition, BET and SEM characterization were used to analyse the catalyst coke deposition.

13/01356 Comparison study of modified asphalt by different coal liquefaction residues and different preparation methods

Wu, M. *et al. Fuel*, 2012, 100, 66–72.

The performance of four coal liquefaction residues (CLRs) in modification of petroleum paving asphalts were investigated. The 40–55 penetration grade modified asphalts were made. ASTM D5710–95 specifications were used to evaluate the modified asphalts. The influence of chemical composition and preparation methods were studied. The results indicate that the performance of CLR mainly depends on the amount and type of its miscible fraction that can dissolve or melt into the base asphalt. The addition of different CLRs in the base asphalt by a conventional hot mixing method results in the similar changes with respect to the softening point and penetration. However, it leads to the different change in ductility. The morphology analysis of the modified asphalt shows that the immiscibles from CLR are dispersed or suspended as single or clustered particles in the continuous asphalt phase. The miscibles of CLR in the base asphalt are active ingredients participating in the modification. The amount and the average molecular weight of CLR's tetrahydrofuran solubles have a close relationship with its performance. The dissolution or dispersion of CLR can be greatly improved with the help of solvent.

13/01357 Effects of hydrogen transfer by exchanged cobalt upon liquefaction of low rank coal

Sugano, M. *et al. Fuel*, 2012, 101, 228–233.

Effect of hydrogen transfer from the pressurized gas or solvent upon liquefaction (with elemental sulfur as an accelerator at 420°C for 1 h) of cobalt exchanged Adaro coal was discussed. Further, catalytic effect of exchanged cobalt upon liquefaction of cobalt exchanged coal was also discussed in comparison with the results after liquefaction of demineralized coal or complex $[(\text{C}_5\text{H}_5)_2\text{Co}$ or $\text{Co}_2(\text{CO})_8]$ added demineralized coal. The amounts of transferred hydrogen from tetralin and the pressurized hydrogen gas upon liquefaction of cobalt exchanged coal with the pressurized hydrogen gas plus any solvent (tetralin, decalin or naphthalene) were almost equal to those of complex added demineralized coal. However, upgrading of cobalt exchanged coal occurred preferentially in comparison with that of complex added coal. In particular, the yield of residue was only 0.3% after liquefaction of cobalt exchanged coal with tetralin plus the pressurized hydrogen gas. Accordingly, liquefaction of cobalt exchanged coal was enhanced significantly by the following two reasons. It was considered that cobalt dispersed finely into the coal macromolecules with attached carboxyl groups irrespective of the size of coal molecule, and hydrogen shuttling through solvent was enhanced by catalytic effect of the dispersed cobalt.

13/01358 Hydrothermal liquefaction of cornelian cherry stones for bio-oil production

Akalin, M. K. *et al. Bioresource Technology*, 2012, 110, 682–687.

Hydrothermal liquefaction of cornelian cherry stones, fruit processing wastes, was performed at 200, 250 and 300°C with residence times of 0, 15, and 30 min. The highest total bio-oil yield was obtained at both 250 and 300°C for the shortest residence time (0 min) and found to be ca. 28 wt.%. The solid residue yields were reduced as both the hydrothermal liquefaction temperature and the holding time was increased. The highest heating values of LBO and HBO were estimated to be 23.86 and 28.35 MJ kg^{-1} , respectively. The major compounds identified in the LBOs were furfurals, phenols, acetic acid and vanillin.

The major components of the HBOs contained furfurals, phenols and fatty acids. Among major identified compounds in the HBOs, the relative concentration of Linoleic acid was the highest both at 250 and 300 °C.

13/01359 Liquid product from hydrothermal treatment of cellulose by direct GC/MS analysis

Wang, Z. *et al. Applied Energy*, 2012, 97, 56–60.

Biomass can be converted to liquid product for fuels and for chemicals by hydrothermal treatment. A method for further treatment of the liquid product much depends on the composition determination, and therefore analysis of the liquid product is important. The much water makes the analysis difficult, while much pretreatment will make the analysis complicated and bring more error sources. Herein hydrothermal treatment of cellulose was carried out, and the liquid product was directly analysed by gas chromatography/mass spectrometry (GC/MS). The major components were identified as some small acids, ketones, some five ring oxygen-containing compounds, and small amounts of some phenol derivatives. Specially, the content of the major component of levulinic acid in two reaction systems are compared, and the effect of the water solvent on the levulinic acid content is discussed. Phenol in the product is specially analysed by MS/MS mode for assurance, and the result confirms the existence of phenol in the liquid product by hydrothermal treatment of cellulose.

13/01360 System aspects of biomass gasification with methanol synthesis – process concepts and energy analysis

Holmgren, K. M. *et al. Energy*, 2012, 45, (1), 817–828.

A systematic analysis of interrelations between different process steps in the biomass gasification and methanol synthesis chain was made. The energy performance of the system is assessed by reviewing previous studies and analysing a case study. Implications of technology choices and process integration opportunities are in focus. The case study analyses the impact on the energy balance of process-integrated drying compared to import of dried biomass, effects on electricity production due to heat pump integration or district heating (DH) delivery, effect on methanol yield of hydrogen addition and the impacts of adding a methanol-to-olefins (MTO) process. The biomass drying has significant impact on the overall energy balance, the cooling demand increases by 60% for the case study installation when process-integrated drying is not applied for drying the biomass. There is a trade-off between methanol yield, electricity and DH production potential of the system. Heat pumping can increase the electricity yield of the system. Hydrogen addition replacing the water gas shift can increase the methanol yield, in the case study by ~35%, but in a stand-alone case the electricity demand makes such a system unrealistic. Adding an MTO unit to the system has limited impact on the energy balance.

13/01361 Testing and estimating time-varying elasticities of Swiss gasoline demand

Neto, D. *Energy Economics*, 2012, 34, (6), 1755–1762.

This paper is intended to test and estimate time-varying elasticities for gasoline demand in Switzerland. For this purpose, a smooth time-varying cointegrating parameters model is investigated in order to describe smooth mutations of the Swiss gasoline demand. The methodology, based on Chebyshev polynomials, is rigorously outlined. The empirical finding states that the time-invariance assumption does not hold for long-run price and income elasticities. Furthermore they highlight that gasoline demand passed through some periods of sensitivity and non-sensitivity with respect to the price. The empirical statements are of great importance to assess the performance of a gasoline tax as an instrument for CO₂ reduction policy. Indeed, such an instrument can contribute to reduce emissions of greenhouse gases only if the demand is not fully inelastic with respect to the price. The results suggest that such a carbon-tax would not be always suitable since the price elasticity is found not stable over time and not always significant.

Tobacco rob (TR) gasification experiments were carried out using thermogravimetric analyser and gas chromatographic analyser. Under the catalytic and non-catalytic condition, the pyrolysis characteristics, gasification characteristics and kinetics of TR were investigated in nitrogen-steam atmosphere. In the gasification process, the volumetric model was used in modelling pyrolysis of TR and the shrinking model was applied for investigating the gasification of pyrolysis chars. The experimental results showed that the TR gasification started above 750 °C without catalysts. Both NiO and dolomite could decrease the gasification temperature and enhance water gas shift reactions. The composition of gasification production was detected by gas chromatograph. The H₂ yield (34 mol/kg) of TR gasification with NiO was the most. The dolomite had more remarkable effect on improving CO yield (23 mol/kg).

13/01363 Experimental investigation of main controls to methane adsorption in clay-rich rocks

Ji, L. *et al. Applied Geochemistry*, 2012, 27, (12), 2533–2545.

In this study a series of CH₄ adsorption experiments on clay-rich rocks were conducted at 35 °C, 50 °C and 65 °C and at CH₄ pressure up to 15 MPa under dry conditions. The clay-dominated rock samples used are fresh samples from quarries and mines. Samples are individually dominated by montmorillonite, kaolinite, illite, chlorite, and inter-stratified illite/smectite. The experimental results show that clay mineral type greatly affects CH₄ sorption capacity under the experimental conditions. In terms of relative CH₄ sorption capacity: montmorillonite >> illite/smectite mixed layer > kaolinite > chlorite > illite. Physisorption is the dominant process for CH₄ adsorption on clay minerals, as a result, there is a linear correlation between CH₄ sorption capacity and BET surface area in these clay-mineral dominated rocks. The abundance of micro-mesopores in the size range of a few to a few tens of nanometres in montmorillonite clay and illite-smectite interstratified clay results in large BET surface area values for these mineral species. A good linear relationship between the natural logarithm of Langmuir constant and the reciprocal of temperature exists for clay-mineral dominated rocks, which provides a way to quantify the impact of clay mineral type on gas adsorption capacity. Thermodynamic parameters, the heat of CH₄ adsorption and the standard entropy, are calculated based on this linear correlations. The heat of adsorption (*q*) and the standard entropy (ΔS°) range from 9.4 to 16.6 kJ/mol and from –64.8 to –79.5 J/mol/K, respectively, values considerably smaller than those for CH₄ adsorption on kerogens. Thus, it is expected that CH₄ molecules may preferentially occupy surface sites on organic matter, in addition, the clay minerals are easily blocked by water. As a consequence, organic-rich mudrocks possess a larger CH₄ sorption capacity than clay-dominated rocks lacking organic matter.

13/01364 Improved lumped-capacitance model for heat and mass transfer in adsorbed gas discharge operations

Sphaier, L. A. and Jurumenha, D. S. *Energy*, 2012, 44, (1), 978–985.

An improved lumped-capacitance formulation for heat and mass transfer in adsorbed gas discharge operations has been developed. The formulation is obtained by employing the coupled integral equations approach (CIEA) for reducing one-dimensional transport equations for adsorbed gas storage in a cylindrical domain to a lumped-capacitance form. The CIEA is based on the traditional Hermite formulas for approximating integrals, which are used for producing relations between average potentials and values at boundaries. This approach is shown to reduce the original spatial-dependent PDEs to two time-dependent ODEs, as similar to the ones obtained using classical lumped-system analyses, the main differences being an additional equation that is required for calculating the reservoir wall temperature, and modified Biot numbers. Two different approximation schemes are tested, and one of them is demonstrated to extend the application range of the classical lumped formulation for Fourier values at least two orders of magnitude smaller than the usual limit seen for this problem.

13/01365 Investigating the pore-scale mechanisms of microbial enhanced oil recovery

Armstrong, R. T. and Wildenschild, D. *Journal of Petroleum Science and Engineering*, 2012, 94–95, 155–164.

Microbial enhanced oil recovery (MEOR) is a process where microorganisms are used for tertiary oil recovery. Numerous mechanisms have been proposed in the literature through which microorganisms facilitate the mobilization of residual oil. This paper focuses on the MEOR mechanisms of interfacial tension reduction (via biosurfactant) and bioclogging in water-wet micromodels, using *Shewanella oneidensis* (MR-1) that causes bioclogging and *Bacillus mojavensis* (JF-2) that produces biosurfactant and causes bioclogging. Micromodels were flooded with an assortment of flooding solutions ranging from metabolically active bacteria to nutrient limited bacteria to dead inactive biomass to assess the effectiveness of the proposed MEOR mechanisms of bioclogging and biosurfactant production. Results

03 GASEOUS FUELS

Sources, properties, recovery, treatment

13/01362 Catalytic gasification of tobacco rob in steam–nitrogen mixture: kinetic study and fuel gas analysis

Yang, Y. *et al. Energy*, 2012, 44, (1), 509–514.

indicate tertiary flooding of the micromodel system with biomass and biosurfactant was optimal for oil recovery due to the combined effects of bioclogging of the pore-space and interfacial tension reduction. However, biosurfactant was able to recover oil in some cases dependent on wettability. Biomass without biosurfactant that clogged the pore-space also successfully produced additional oil recovery. When analysing residual oil blob morphology, MEOR resulted in oil blob size and radius of curvature distributions similar to those obtained by an abiotic capillary desaturation test, where flooding rate was increased post-secondary recovery. Furthermore, for the capillary number calculated during MEOR flooding with bioclogging and biosurfactant, lower residual oil saturation was measured than for the corresponding capillary number under abiotic conditions. These results suggest that bioclogging and biosurfactant MEOR is a potentially effective approach for pore morphology modification and thus flow alteration in porous media that can have a significant effect on oil recovery beyond that predicted by capillary number.

Transport, storage

13/01366 Gas pipeline preferential site selection occurrence for elemental sulphur & other particle matter formation & deposition

Pack, D. J. *et al. Journal of Petroleum Science and Engineering*, 2012, 94–95, 12–18.

Field observations of 'elemental sulfur' deposits within high-pressure natural gas transmission pipeline systems have prompted investigations into the study of preferential site selection process for the formation and deposition of these sulfur-based contaminants. These deposits can cause complete blockage of the gas stream path. There have not been any known studies into why this preferential site selection process exists, and therefore it is the aim of this research to investigate plausible reasons by investigating affected pipeline systems. The results from the studies, which have been validated against known 'elemental sulfur' affected transmission pipeline sites, confirm that the flow dynamics at the pipeline 'T'-junction could be a major contributing factor to the preferential site selection process.

13/01367 Gas storage, transport and pressure changes in an evolving permeable volcanic edifice

Collinson, A. S. D. and Neuberg, J. W. *Journal of Volcanology and Geothermal Research*, 2012, 243–244, 1–13.

The total volume of gas in a magma, dissolved and subsequently exsolved, greatly influences the degree of explosiveness of a volcanic system. There is a marked contrast between the behaviour of a volcano in an 'open' system compared to one which is 'closed'. It is therefore essential to understand the entire degassing process: gas transport, storage and loss. A particular focus of this study is the effect different permeabilities and pressure gradients within a volcanic edifice have on the degree and pattern of the gas velocity. Gas loss is modelled numerically in two dimensions using a finite element approach, which allows the specification of boundary conditions with respect to pressure and different permeability domains within the volcanic edifice. By combining the time-dependent continuity equation and Darcy's law, a partial differential equation is derived and solved for the pressure. The associated pressure gradient is then used within Darcy's law to determine the corresponding gas velocity distribution. This method is used not only for stationary systems in equilibrium, but also as a time-dependent progression. It permits the modelling of different situations to study how various volcanic characteristics affect the gas loss. The model is used to investigate the change in pressure and gas in response to time-dependent scenarios. These are a dome collapse or sudden increase in permeability by magma rupture at the conduit margin, the formation of cracks within the lava dome and sealing by crystallization. The results show that a combination of high and low permeability regions is required for effective gas storage. High permeability allows the gas to enter the system, but impermeable areas act to confine the gas, thereby increasing its pressure and consequently, increasing the amount of gas which may be dissolved in the melt. Furthermore, the results show that permeability is an essential factor influencing the response time to system changes, which could be linked in future to deformation and other geophysical observations. This model is highly versatile and sheds new light on the understanding of gas storage and transport in a permeable volcanic edifice.

13/01368 Nanosize Zr-metal organic framework (UiO-66) for hydrogen and carbon dioxide storage

Abid, H. R. *et al. Chemical Engineering Journal*, 2012, 187, 415–420. A nanosize Zr-metal organic framework (Zr-MOF, UiO-66) with a uniformed particle size around 100 nm was solvothermally synthesized and activated by solvent exchange method, vacuum drying and heating.

The activation process with an exchangeable guest solvent produced the Zr-MOF with a high surface area by removal almost all guest and free terephthalic acid molecules from the pores enhancing its capacity for adsorption. The nanosize Zr-MOF also showed strong thermal stability up to 753 K. The Zr-MOF was tested for hydrogen and carbon dioxide adsorption at varying pressures and temperatures and it exhibited adsorption capacity of 1.6 wt% (H_2) at 1 atm, 77 K and 79 cc (CO_2) g^{-1} at 1 atm, 273 K, respectively. The heat of H_2 adsorption was determined to be 6–12 kJ mol $^{-1}$ while the heat of CO_2 adsorption was determined to be around 28 kJ mol $^{-1}$.

13/01369 Real gas flow simulation in damaged distribution pipelines

Kostowski, W. J. and Skorek, J. *Energy*, 2012, 45, (1), 481–488.

The paper discusses chosen issues concerning damaged gas pipelines. Attention is paid to modelling the steady-state flow of natural gas in distribution pipelines, and the most commonly applied models of isothermal and adiabatic flow are evaluated for both the ideal and the real gas properties. A method of accounting for a leakage by means of a reference flow equation with a discharge coefficient is presented, and the dependency of the discharge coefficient on pressure is demonstrated both with literature data and the authors' experimental results. A relevant computational study of a pipeline failure is presented for a high- and a medium-pressure pipeline. The importance of an appropriate choice of the flow model (isothermal or adiabatic flow of real or ideal gas) is demonstrated by the results of the study. It is shown that accounting for the variability of the discharge coefficient is required if medium pressure pipelines are analysed. However, the impact of the discharge coefficient on the predicted outflow rate is of lesser importance than that of the applied flow model.

13/01370 The cost of natural gas shortages in Ireland

Leahy, E. *et al. Energy Policy*, 2012, 46, 153–169.

This paper investigates the economic implications of disruptions of 1–90 days to the supply of natural gas in Ireland. The authors assess the impact of a hypothetical gas supply disruption in both winter and summer in 2008 (with observed market characteristics) and in 2020 (with projected market characteristics). The cost of a natural gas outage includes the cost of natural gas being unavailable for heating and other purposes in the industrial and commercial sectors, lost consumer surplus in the residential sector, the cost of lost electricity in all sectors and lost value-added tax on the sale of gas and electricity. Ireland generates much of its electricity from natural gas and the loss of this electricity accounts for the majority of the cost of a natural gas outage. Losing gas-fired electricity would cost €0.1–1.0 billion per day, depending on the time to the week, the time of year and rationing. Industry should be rationed before households to minimize economic losses, but current emergency protocols do the opposite. If gas-fired electricity is unavailable for three months, the economic loss could be up to €80 billion, about half of gross domestic product. Losing gas for heating too would add up to approximately €8 billion in economic losses. The authors also discuss some options to increase Ireland's security of supply, and find that the cost is a small fraction of the avoided maximum damage.

13/01371 The positive displacement method for calibration of gas flow meters. The influence of gas compressibility

Pinho, C. *Applied Thermal Engineering*, 2012, 41, 111–115.

An easy technique to calibrate small gas flow meters is the positive displacement method, whose application requires a simple setup and laboratory procedure. With this methodology there is an unknown gas flow coming from a given gas source that must be known by the action of a gas flow meter. The gas flow to be measured is sent to a reservoir with rigid walls and full of water. As gas enters the reservoir water flows out and the amount of water exiting the reservoir in a given time interval can be connected with the average gas flow in that same time interval. In simple terms the volume flow rate of water leaving the reservoir is equal to the gas volume flow rate entering it. The water being incompressible, the density variation is meaningless, however the same cannot be assumed for the gas. Considerations on the simple techniques to be used to minimize the importance of gas compressibility are presented in the paper.

Economics, business, marketing, policy

13/01372 A decision support model for combined heat and power economic evaluation

Konstantakos, V. *et al. Applied Thermal Engineering*, 2012, 42, 129–135.

Many European states support combined heat and power (CHP) investments and provide better selling tariffs for the electricity produced. In this paper, a model was developed that can help energy planning and decision-making for CHP investments in an unstable energy market. The model uses as variables state subsidies, natural gas and electricity selling price. Five different scenarios from Greek economic reality had been used in order to evaluate their economic viability and the investment risk. Finally, a sensitivity analysis was carried out, having as variables the natural gas price and the state subsidy. The sensitivity analysis of the natural gas price showed that although profits decrease as natural gas price increases, the investment remains viable for almost twice the current natural gas price. This means that small fluctuations of natural gas price do not affect the investment to a crucial degree.

13/01373 Civil unrest in North Africa – risks for natural gas supply?

Lochner, S. and Dieckhöner, C. *Energy Policy*, 2012, 45, 167–175.
The uprising and military confrontation in Libya that began in February 2011 has led to disruptions of gas supplies to Europe. An analysis of how Europe has compensated for these missing gas volumes shows that this situation has not affected security of supply. However, this situation would change if the North African uprising were to spread to Algeria. Since Algeria is a much more important gas supplier to Europe than is Libya, more severe consequences would be likely. Applying a natural gas infrastructure model, the authors investigate the impact of supplier disruptions from both countries for a summer and winter period. The analysis shows that disruptions in the low-demand summer months could be compensated for, mainly by liquefied natural gas imports into several European countries. An investigation of a similar situation at the beginning of the winter shows that security of supply would be severely compromised and that disruptions to Italian consumers would be unavoidable. The analysis thereby highlights the importance of taking the political stability of supply countries into account when assessing the security of European gas imports.

13/01374 Comparative analysis of energy storage options in connection with coal fired integrated gasification combined cycles for an optimised part load operation

Rezvani, S. *et al. Fuel*, 2012, 101, 154–160.
A large number of research undertakings and system modelling works study different coal fired integrated gasification combined cycle (IGCC) configurations, mostly with the conflicting purposes and aims, to increase system efficiencies, to reduce costs and to diminish environmental impacts. The increased penetration levels of intermittent renewable energy systems experienced in many parts of the world, however, makes the establishment of flexible power generation systems to be a more challenging task. The integration of a diurnal syngas storage system as a means to increase system flexibility is investigated in this work with reference to different syngas qualities. All the systems are based on a reference coal-fired IGCC power plant. The system modification is limited to the gas processing units including a CO₂ removal option allowing for different syngas compositions. Apart from the reference syngas, four further options are proposed here: hydrogen rich syngas with and without a carbon capture, a scenario with a partial carbon capture and finally a synthetic natural gas (SNG) production case. The techno-economic analysis is implemented in connection with a short-term geological syngas/hydrogen rich gas storage reservoir. The results show that a hydrogen rich gas generation without a carbon capture will be techno-economically less attractive and requires a relatively large reservoir volume. A methanation process towards a SNG production adds significantly to the overall cost and reduces the cold gas efficiency. The storage volume requirement is however considerably reduced. Finally, a short comparison will be drawn to a potential case configuration with a compressed air energy storage system.

13/01375 Gas release and transport capacity investment as instruments to foster competition in gas markets

Chaton, C. *et al. Energy Economics*, 2012, 34, (5), 1251–1258.
Motivated by policy events experienced during the last two decades by the European natural gas industry, this paper develops a simple model for analysing the interaction between gas release and capacity investment programs as tools to improve the performance of imperfectly competitive markets. The authors consider a regional market in which a measure that has an incumbent release part of its gas to a marketer complements a programme of investment in transport capacity dedicated to imports by the marketer, at a regulated transport charge, of competitively-priced gas. First, they examine the case where transport capacity is regulated while gas release is not, i.e. the volume of gas released is determined by the incumbent. They then analyse the effect of the 'artificial' duopoly created by the regulator when the latter regulates both gas release and transport capacity. Finally, using information on the French industry, the authors calibrate the basic demand and cost elements of the model and perform some simulations

of these two scenarios. Besides allowing the analysis of the economic properties of these scenarios, a policy implication that comes out of the empirical analysis is that, when combined with network expansion investments, gas-release measures applied under regulatory control are indeed effective short-term policies for promoting gas-to-gas competition.

13/01376 'Greenwashing gas: might a 'transition fuel' label legitimize carbon-intensive natural gas development?'

Stephenson, E. *et al. Energy Policy*, 2012, 46, 452–459.
Natural gas is widely considered to be the crucial 'bridging fuel' in the transition to the low-carbon energy systems necessary to mitigate climate change. This paper develops a case study of the shale gas industry in British Columbia (BC), Canada to evaluate this assumption. The authors find that the transition fuel argument for gas development in BC is unsubstantiated by the best available evidence. Emissions factors for shale gas and liquefied natural gas remain poorly characterized and contested in the academic literature, and context-specific factors have significant impacts on the lifecycle emissions of shale gas but have not been evaluated. Moreover, while the province has attempted to frame natural gas development within its ambitious climate change policy, this framing misrepresents substantive policy on gas production. The 'transition fuel' and 'climate solution' labels applied to development by the BC provincial government risk legitimizing carbon-intensive gas development. The authors argue that policy makers in BC and beyond should abandon the 'transition fuel' characterization of natural gas. Instead, decision making about natural gas development should proceed through transparent engagement with the best available evidence to ensure that natural gas lives up to its best potential in supporting a transition to a low-carbon energy system.

13/01377 Influence of extensive compressed natural gas (CNG) usage on air quality

Suthawaree, J. *et al. Atmospheric Environment*, 2012, 54, 296–307.
Compressed natural gas (CNG) is an inexpensive, indigenous energy resource which currently accounts for the majority of automobile and domestic energy consumption in Bangladesh. This extensive CNG usage, particularly within the capital city, Dhaka, heavily influences the atmospheric composition (and hence air quality), yet to date measurements of trace gases in regions dominated by CNG emissions are relatively limited. Here the authors report continuous observations of the atmospherically important trace gases O₃, CO, SO₂, NO_x and volatile organic compounds (VOC), in ambient air in Dhaka City, Bangladesh, during May 2011. The average mixing ratios of O₃, CO, SO₂, and NO_x for the measurement period were 18.9, 520.9, 7.6 and 21.5 ppbv, respectively. The ratios of CO to NO reveal that emissions from gasoline and CNG-fuelled vehicles were dominant during the daytime (slope of ~26), while in contrast, owing to restrictions imposed on diesel fuelled vehicles entering Dhaka City, emissions from these vehicles only became significant during the night (slope of ~10). The total VOC mixing ratio in Dhaka was ~5–10 times higher than the levels reported in more developed Asian cities such as Tokyo and Bangkok, which consequently gives rise to a higher ozone formation potential (OFP). However, the most abundant VOC in Dhaka were the relatively long-lived ethane and propane (with mean mixing ratios of ~115 and ~30 ppbv, respectively), and as a consequence, the ozone formation potential per ppb carbon (ppbC) was lower in Dhaka than in Tokyo and Bangkok. Thus the atmospheric composition of air influenced by extensive CNG combustion may be characterized by high VOC mixing ratios, yet mixing ratios of the photochemical pollutant ozone do not drastically exceed the levels typical of Asian cities with considerably lower VOC levels.

13/01378 Investigation of hydrogen usage in aviation industry

Yilmaz, I. *et al. Energy Conversion and Management*, 2012, 63, 63–69.
This study reports a research about aircraft gas turbine engines which are fired by liquid hydrogen (LH₂) in terms of performance and environmental aspects. Also, the performance and emissions of LH₂-fuelled engines are compared with those of kerosene-fired aircraft engines. Same flights from Istanbul to London, and Paris to Kabul are examined to estimate the emission from a conventional aircraft as an application in aviation sector. It is shown that the amount of NO_x, HC and CO emissions for travelling by a conventional aircraft for London is 78.36, 1.202 and 22.4 kg, while Paris is 71.55, 1.171 and 21.63 kg, and Kabul is 111.44, 1.36 and 26.11 kg, respectively. For the use of liquid hydrogen as a fuel, amount of gas emissions decreases for any destination like London, Paris and Kabul. Total HC and CO emissions are going to be nearly 0 kg because of lack of carbon in the fuel. Also NO_x emission is lower because of wider flammability limit of LH₂. Results show that the aircraft engines with LH₂ have great potential for emissions reduction and engine performance parameters are a little better for LH₂ fuel. It is strongly emphasized that one of the most important advantages for the use of LH₂ is national independence for

fuel supply. Oil cannot be extracted in every country's territory but LH_2 is producible for every country and this is important for a country's freedom.

13/01379 On the volatility–volume relationship in energy futures markets using intraday data

Chevallier, J. and Sévi, B. *Energy Economics*, 2012, 34, (6), 1896–1909. This paper investigates the relationship between trading volume and price volatility in the crude oil and natural gas futures markets when using high-frequency data. By regressing various realized volatility measures (with/without jumps) on trading volume and trading frequency, the results feature a contemporaneous and largely positive relationship. Furthermore, the authors test whether the volatility–volume relationship is symmetric for energy futures by considering positive and negative realized semivariances. They show that (i) an asymmetric volatility–volume relationship indeed exists, (ii) trading volume and trading frequency significantly affect negative and positive realized semivariance, and (iii) the information content of negative realized semivariance is higher than for positive realized semivariance.

13/01380 Persistence in natural gas consumption in the US: an unobserved component model

Golpe, A. A. *et al. Energy Policy*, 2012, 46, 594–600.

This article re-examines the persistence in natural gas consumption using an alternative methodology. In particular it reports estimates of an unobserved components model, in which hysteresis exists if cyclical and natural gas consumptions do not evolve independently. In addition, this framework is also extended by using the non-linear approach, in which non-linearities are introduced by allowing past cyclical component to have a different impact on the natural component depending on the regime. In a linear framework, the results seem to indicate that hysteresis does not exist. However, when non-linearity is taken into account, evidence is provided in favour of hysteresis in natural gas consumption when the variations in natural gas consumption are above the threshold value. The authors also selectively survey the empirical literature that examines the long-term properties of energy series in order to put this contribution in perspective.

13/01381 The Arctic: no big bonanza for the global petroleum industry

Lindholt, L. and Glomsrød, S. *Energy Economics*, 2012, 34, (5), 1465–1474.

Petroleum companies and Arctic states are carefully watching the sea ice withdrawal and the future access to petroleum resources in the Arctic. The authors here raise the question whether the global market for petroleum will actually keep the door open for substantial supply of oil and gas from the Arctic, a region with almost a quarter of global undiscovered petroleum resources, but at high costs and long lead times. This makes future Arctic supply highly dependent on oil and gas prices, influenced by future supply of unconventional oil and gas and also by huge amounts of conventional gas in the Middle East coming on stream. Oil and gas supplies were studied from six Arctic regions during 2010–2050 using the FRISBEE model of global oil and gas markets, based on Arctic resource estimates from the US Geological Survey. Following the IEA reference oil price assumption, it was found that even if almost a quarter of the world's undiscovered petroleum is situated in Arctic basins, the future share of global production will only be 8–10% in this reference scenario. Although a major part of the undiscovered Arctic resources is natural gas, the relative importance of the Arctic as a world gas supplier will decline, while its relative importance as a global oil producer might be maintained. Less undiscovered oil resources will have minor effect on total Arctic oil production and a marginal effect on Arctic gas extraction as Arctic Russia is the dominant petroleum producer with a sufficiently large stock of already discovered resources at relatively low costs to support their petroleum production before 2050.

13/01382 The effects of a natural gas boom on employment and income in Colorado, Texas, and Wyoming

Weber, J. G. *Energy Economics*, 2012, 34, (5), 1580–1588.

Improvements in technology have made it profitable to tap unconventional gas reservoirs in relatively impermeable shale and sandstone deposits, which are spread throughout the USA, mostly in rural areas. Proponents of gas drilling point to the activity's local economic benefits yet no empirical studies have systematically documented the magnitude or distribution of economic gains. These gains are estimated for counties in Colorado, Texas, and Wyoming, three states where natural gas production expanded substantially since the late 1990s. The author found that a large increase in the value of gas production caused modest increases in employment, wage and salary income, and median household income. The results suggest that each million dollars in gas production created 2.35 jobs in the county of production, which led to an annualized increase in employment that was 1.5% of the pre-boom

level for the average gas boom county. Comparisons show that *ex ante* estimates of the number of jobs created by developing the Fayetteville and Marcellus shale gas formations may have been too large.

13/01383 Vehicle refueling with liquid hydrogen thermal compression

Petipas, G. *et al. International Journal of Hydrogen Energy*, 2012, 37, (15), 11448–11457.

The authors have modelled an approach for dispensing pressurized hydrogen to 350 and/or 700 bar vehicle vessels. Instead of relying on compressors, this concept stores liquid hydrogen in cryogenic pressure vessels where pressurization occurs through heat transfer, reducing the station energy footprint from 12 kWh/kgH₂ of energy from the US grid mix to 1.5–2 kWh/kgH₂ of heating. This thermal compression station presents capital cost and reliability advantages by avoiding the expense and maintenance of high-pressure hydrogen compressors, at the detriment of some evaporative losses. The total installed capital cost for a 475 kg/day thermal compression hydrogen refuelling station is estimated at about \$611,500, an almost 60% cost reduction over today's refuelling station cost. The cost for 700 bar dispensing is \$5.23/kg H₂ for a conventional station vs \$5.45/kg H₂ for a thermal compression station. If there is a demand for 350 bar H₂ in addition to 700 bar dispensing, the cost of dispensing from a thermal compression station drops to \$4.81/kg H₂, which is similar to the cost of a conventional station that dispenses 350 bar H₂ only. Thermal compression also offers capacity flexibility (wide range of pressure, temperature, and station demand) that makes it appealing for early market applications.

Derived gaseous fuels

13/01384 An evaluation of substitute natural gas production from different coal gasification processes based on modeling

Karellas, S. *et al. Energy*, 2012, 45, (1), 183–194.

Coal and lignite will play a significant role in the future energy production. However, the technical options for the reduction of CO₂ emissions will define the extent of their share in the future energy mix. The production of synthetic or substitute natural gas (SNG) from solid fossil fuels seems to be a very attractive process: coal and lignite can be upgraded into a methane rich gas which can be transported and further used in high efficient power systems coupled with CO₂ sequestration technologies. The aim of this paper is to present a modelling analysis comparison between substitute natural gas production from coal by means of allothermal steam gasification and autothermal oxygen gasification. In order to produce SNG from syngas several unit operations are required such as syngas cooling, cleaning, potential compression and, of course, methanation reactors. Finally the gas which is produced has to be conditioned, i.e. removal of unwanted species, such as CO₂, etc. The heat recovered from the overall process is utilized by a steam cycle, producing power. These processes were modelled with the computer software IPSEpro™. An energetic and exergetic analysis of the coal to SNG processes have been realized and compared.

13/01385 Biomass steam gasification for production of SNG – process design and sensitivity analysis

Gröbl, T. *et al. Applied Energy*, 2012, 97, 451–461.

A process design for small-scale production of substitute natural gas (SNG) by steam gasification of woody biomass is performed. In the course of this work, thermodynamic models for the novel process steps are developed and implemented into an already existing model library of commercial process simulation software IPSEpro. Mathematical models for allothermal steam gasification of biomass as well as for cleaning and methanation of product gas are provided by applying mass balances, energy balances and thermodynamic equilibrium equations. Using these models the whole process is integrated into the simulation software, a flowsheet for an optimum thermal integration of the single process steps is determined and energy savings are identified. Additionally, a sensitivity study is carried out in order to analyse the influence of various operation parameters. Their effects on amount and composition of the product gas and process efficiency are evaluated and discussed within this article.

13/01386 Catalytic upgrading of syngas from fluidized bed air gasification of sawdust

Huang, B.-S. *et al. Bioresource Technology*, 2012, 110, 670–675.

This study was conducted to investigate the effects of various gasification temperatures in a fluidized bed gasifier on biomass-derived products and to evaluate the efficiency of syngas upgraded by a secondary catalytic reactor. The results indicated that biomass vaporization was clearly affected by gasification temperature, resulting

in the obtained products having different composition ratios. Additionally, the hydrogen promotion ratios were found to be strongly dependent on the condensable products, indicating that the products were upgraded via the use of a catalyst in the secondary reactor. If biomass vaporized at suitable gasification temperatures can produce a large amount of condensable products, the products could be effectively upgraded for hydrogen production by the secondary catalytic reactor under very mild conditions (250 °C). Overall, the process not only upgraded hydrogen production, but also degraded contaminants; therefore, its implementation should reduce the cost of operation and pollution control in the biomass-to-energy industry.

13/01387 Classification procedure of the explosion risk areas in presence of hydrogen-rich syngas: biomass gasifier and molten carbonate fuel cell integrated plant

Molino, A. *et al. Fuel*, 2012, 99, 245–253.

This paper deals with the safety aspects of a 500 kW_{th} (thermal power) biomass gasification plant coupled with a 125 kW_e (electric power) molten carbonate fuel cell. In particular, it describes the procedure for assessing the explosion risk in presence of hydrogen-rich syngas and compares the results given by the application of technical standards with those obtained by the implementation of a fluid dynamic model for the potential emission scenarios.

13/01388 Exergy analysis of underground coal gasification with simultaneous storage of carbon dioxide

Eftekhari, A. A. *et al. Energy*, 2012, 45, (1), 729–745.

Various options are considered to reduce CO₂ emissions when utilizing deep coal by applying underground coal gasification (UCG), i.e. in combination with carbonation of synthetic minerals (CaO), conventional UCG followed by *ex situ* separation of CO₂ and upgrading the product gas using naturally occurring minerals (wollastonite). A chemical equilibrium model was used to analyse the effect of process parameters on product composition and use it for an exergy analysis. The result is presented in terms of theoretical (ideal unit operations), practical (state of the art technology), and zero-emission [applying current CO₂ capture and sequestration technology (CCS) to all sources of CO₂ emission] recovery factors. The results show that underground gasification of deep coal can optimally extract 52–68% of the coal chemical exergy, but zero-emission extraction gives a negative recovery indicating that it is not practical with current state of the art CCS technology. Using *in situ* CaO, which will enhance the H₂ production, is theoretically feasible with a recovery factor around 80%, but is not exergetically feasible with the current state of technology. *Ex situ* upgrading of the conventional UCG product gas with wollastonite is exergetically feasible for both practical and zero-emission cases according to the equilibrium model.

13/01389 Influence of pressure, temperature and steam on tar and gas in allothermal fluidized bed gasification

Mayerhofer, M. *et al. Fuel*, 2012, 99, 204–209.

Gasification is considered to be a promising way to use biomass with high efficiency in combined heat and power production, for the production of second-generation biofuels and in the chemical industry. Especially allothermal fluidized bed steam gasification produces a medium calorific, nitrogen free gas suitable for a variety of downstream processes. In general the raw product gas has to be cleaned from condensable hydrocarbons (tar) and conditioned (e.g. adjustment of the H₂/CO-ratio) before downstream use. The operating conditions of the gasification reactor have a large impact on the quality of the product gas. Hence first steps to a product gas low in tar content can be undertaken directly in the reactor. In this study the capability of influencing the tar content and gas composition by changing temperature (750–840 °C), steam to biomass (S/B) ratio (0.8–1.2) and pressure (0.1–0.25 MPa) in an allothermal bubbling fluidized bed steam gasifier is investigated. It is found that rising temperature reduces the total tar content and affects especially heterocyclic and light aromatic compounds. At atmospheric pressure the naphthalene content increases slightly with increasing temperature in contrary to pressurized gasification where naphthalene decreases significantly with increasing temperature. An increase in the S/B ratio leads to a decreasing total tar content, this tar reduction according to a higher steam content is higher at higher temperatures. Increasing pressure leads to increasing total tar content mainly due to naphthalene, the effect is most distinct for low S/B ratios.

13/01390 Methanol decomposition on electrospun zirconia nanofibers

Ruiz-Rosas, R. *et al. Catalysis Today*, 2012, 187, (1), 77–87.

Electrospinning has been used for the preparation of PVP–zirconium acetate nanofibers. The obtained non-woven cloths have been calcined at different temperatures (200–1000 °C) and used as heterogeneous catalysts in the gas phase decomposition of methanol. The X-ray diffraction spectra of the zirconia nanofibers show the onset of a semicrystalline tetragonal structure for the fibres calcined at 400 °C.

Transformation from tetragonal to monoclinic zirconia starts at a calcination temperature between 600 and 800 °C. SEM and TEM images of the zirconia nanofibers show fibres with a high aspect ratio and sizes as thin as 200 nm. The increase of the calcination temperature results in zirconia fibre catalysts with lower methanol steady state conversions, probably due to changes in the crystalline phase and crystal sintering. The fibres calcined at 500 °C yielded the highest methanol conversion and selectivities to dimethyl ether. In general trend, methanol dehydrates to dimethyl ether at the lower reaction temperatures and decomposes to hydrogen and carbon monoxide at the higher reaction temperatures. Deactivation of the catalyst is observed only at the highest reaction temperature, being probably related to deposition over the fibre surface of pyrolytic carbon from cracking reaction of dimethyl ether.

13/01391 Poverty and growth impacts of high oil prices: evidence from Sri Lanka

Naranpanawa, A. and Bandara, J. S. *Energy Policy*, 2012, 45, 102–111.

The sharp rise in oil and food prices in 2007 and 2008 caused negative impacts on poverty and economic growth in many oil and food importing developing countries. Some analysts believe that these countries are under stress again due to a rise in crude oil prices, to a two-and-a-half year high in March 2011, which has also been partly responsible for higher food prices in recent months. However, there is a limited body of empirical evidence available from developing countries on the impact of high oil prices on growth in general and household poverty in particular. In this study, Sri Lanka is used as a case study and a computable general equilibrium approach is adopted as an analytical framework to explore the growth and poverty impacts of high oil prices. The results suggest that urban low income households are the group most adversely affected by high global oil prices, followed by low income rural households. In contrast, estate low income households are the least affected out of all low income households. The energy intensive manufacturing sector and services sector are affected most compared to the agricultural sector.

13/01392 Syngas fermentation to biofuels: effects of ammonia impurity in raw syngas on hydrogenase activity

Xu, D. *et al. Biomass and Bioenergy*, 2012, 45, 303–310.

Hydrogenase activity plays an important role in the fermentation of biomass-generated syngas (containing CO, CO₂ and H₂) to obtain ethanol and other biofuels. One process efficiency issue for producing biofuels from syngas fermentation is the ability of key cellular enzymes to produce reducing equivalents from syngas. For microbes using the Wood–Ljungdahl pathway, inhibition of the hydrogenase enzyme would decrease reducing equivalent production from H₂, thus potentially reducing carbon conversion efficiency and biofuel production. During biomass gasification to produce syngas, several impurities are generated. These impurities, such as ammonia (NH₃), can potentially impact the fermentation process. In this work, it was shown that NH₃ rapidly converts to ammonium ion (NH₄⁺) following exposure of fermentation media to NH₃. The accumulated NH₄⁺ also inhibited hydrogenase activity and cell growth. A kinetic model for hydrogenase activity that included inhibition effects from NH₄⁺ was developed. Model parameters included K_{H₂} (Michaelis–Menten constant) and K_{NH₄⁺} (the inhibition constant for NH₄⁺). Experimental results showed that NH₄⁺ is a non-competitive inhibitor for hydrogenase activity with K_{NH₄⁺} of (649 ± 35) mol m⁻³. As part of the work to distinguish the unique aspect of NH₄⁺ inhibition, additional work showed that potassium and phosphate ions had no effect on hydrogenase activity. Since NH₄⁺ can easily be accumulated in fermentation media and transport across the cell membrane, it is necessary to remove NH₃ impurity from raw syngas to minimize the reduction in hydrogenase activity.

13/01393 Syngas production by catalytic steam gasification of municipal solid waste in fixed-bed reactor

Luo, S. *et al. Energy*, 2012, 44, (1), 391–395.

The catalytic steam gasification of municipal solid waste for syngas production was conducted in a lab-scale fixed-bed reactor. The influence of the reactor temperature, steam to carbon ratio (S/C) and catalyst type (NiO/γ-Al₂O₃ or calcined dolomite) on the gas yield, gas composition, H₂/CO molar ratio and carbon conversion efficiency were investigated. The results indicated that increasing reactor temperature resulted in greater gas production in the initial pyrolysis and improved endothermic reactions (gasification of char, catalytic cracking and reforming of tar), which resulted in the increase of syngas yield. Compared with MSW catalytic pyrolysis, the introduction of steam leads to more tar and char participating in steam gasification, which resulted in a rapid increase of syngas yield and carbon conversion efficiency. NiO/γ-Al₂O₃ catalyst revealed better catalytic performance for the cracking of tar than calcined dolomite. The highest H₂ content (54.22%) and gas yield (1.75 N m³/kg) were achieved at 900 °C, S/C being 2.41 with NiO/γ-Al₂O₃ as catalyst.

13/01394 Syngas production by two-stage method of biomass catalytic pyrolysis and gasificationXie, Q. *et al. Bioresource Technology*, 2012, 110, 603–609.

A two-stage technology integrated with biomass catalytic pyrolysis and gasification processes was utilized to produce syngas ($H_2 + CO$). In the presence of different nickel based catalysts, effects of pyrolysis temperature and gasification temperature on gas production were investigated. Experimental results showed that more syngas and char of high quality could be obtained at a temperature of 750 °C in the stage of pyrolysis, and in the stage of gasification, pyrolysis char (produced at 750 °C) reacted with steam and the maximum yield of syngas was obtained at 850 °C. Syngas yield in this study was greatly increased compared with previous studies, up to 3.29 Nm³/kg biomass. The pyrolysis process could be well explained by Arrhenius kinetic first-order rate equation. XRD analyses suggested that formation of Mg_{0.4}Ni_{0.6}O and increase of Ni⁰ crystallite size were two main reasons for the deactivation of nickel based catalysts at higher temperature.

13/01395 Synthetic gas production from dry black liquor gasification process using direct causticization with CO₂ captureNaqvi, M. *et al. Applied Energy*, 2012, 97, 49–55.

Synthetic natural gas (SNG) production from dry black liquor gasification (DBLG) system is an attractive option to reduce CO₂ emissions replacing natural gas. This article evaluates the energy conversion performance of SNG production from oxygen blown circulating fluidized bed (CFB) black liquor gasification process with direct causticization by investigating system integration with a reference pulp mill producing 1000 air-dried tonnes (ADt) of pulp per day. The direct causticization process eliminates use of energy intensive lime kiln that is a main component required in the conventional black liquor recovery cycle with the recovery boiler. The paper has estimated SNG production potential, the process energy ratio of black liquor (BL) conversion to SNG, and quantified the potential CO₂ abatement. Based on reference pulp mill capacity, the results indicate a large potential of SNG production (about 162 MW) from black liquor but at a cost of additional biomass import (36.7 MW) to compensate the total energy deficit. The process shows cold gas energy efficiency of about 58% considering black liquor and biomass import as major energy inputs. About 700 ktonnes per year of CO₂ abatement, i.e. both possible CO₂ capture and CO₂ offset from bio-fuel use replacing natural gas, is estimated. Moreover, the SNG production offers a significant fuel replacement in transport sector especially in countries with large pulp and paper industry, e.g. in Sweden, about 72% of motor gasoline and 40% of total motor fuel could be replaced.

LNG

13/01396 Environmental assessment of two pathways towards the use of biofuels in shippingBengtsson, S. *et al. Energy Policy*, 2012, 44, 451–463.

The goal of this study is to evaluate the life cycle performance of two alternative pathways to biofuels in the shipping industry: the 'diesel route' and the 'gas route'. The diesel route comprises of a shift from heavy fuel oil to marine gas oil and then a gradual shift to biodiesel, whereas the gas route comprises of a shift to liquefied natural gas and then a gradual shift to liquefied biogas. The two routes are assessed in a case study for the ferry traffic between the Swedish mainland and the island Gotland. Life cycle assessment is used to evaluate the environmental performance with the functional unit chosen to be one year of ro-pax ferry service, including both passenger and goods transportation. The gas route is indicated to have better overall environmental performance than the diesel route. Furthermore, use of biofuels is illustrated as one possible measure to decrease the global warming impact from shipping, but to the expense of greater environmental impact for some other impact categories. As an example, the global warming potential was shown to decrease with the use of biofuels in this study, while the eutrophication potential and the primary energy use increased.

13/01397 Hydrogen production by steam reforming of liquefied natural gas (LNG) over mesoporous nickel–alumina xerogel catalysts prepared by a single-step carbon-templating sol–gel methodBang, Y. *et al. International Journal of Hydrogen Energy*, 2012, 37, (15), 11208–11217.

A series of mesoporous nickel–alumina xerogel catalysts (denoted as CNAX) were prepared by a single-step carbon-templating sol–gel method using different amount of carbon template (X), and they were applied to the hydrogen production by steam reforming of liquefied natural gas (LNG). Textural properties of CNAX catalysts were

improved with increasing the amount of carbon template. CNAX catalysts exhibited diffraction peaks corresponding to nickel aluminate phase, while CNA18 and CNA24 catalysts showed additional bulk nickel oxide phase. From TPR measurements, it was revealed that the interaction between nickel species and alumina in the CNAX catalysts became weakened with increasing the amount of carbon template. Crystallite size of metallic nickel in the reduced CNAX catalysts showed a volcano-shaped trend with respect to the amount of carbon template. In the steam reforming of LNG, CNAX ($X = 0, 6, 12$, and 18) catalysts exhibited a stable catalytic performance during the reaction, while CNA24 catalyst showed a significant catalyst deactivation. Crystallite size of metallic nickel served as an important factor determining the catalytic performance in the steam reforming of LNG. Initial LNG conversion and initial hydrogen yield increased with decreasing crystallite size of metallic nickel of the catalysts. Among the catalysts tested, CNA12 catalyst with the smallest crystallite size of metallic nickel showed the best catalytic performance.

13/01398 Modeling Turkey's future LNG supply security strategyBiresellioglu, M. E. *et al. Energy Policy*, 2012, 46, 144–152.

Turkey was among those countries which decided to increase its natural gas consumption in the 1990s, due to its relative low cost and lack of impact on the environment. However, a heavy dependence on imports, from Algeria, Qatar and Nigeria, respectively, creates a threat to energy security, both in terms of source and supply diversity. Accordingly, the authors follow an analytical approach to identify the accuracy of this assumption, considering the current economic, political and security risk. To this end, they formulate and solve a mixed integer programming model that determines the optimal sourcing strategy for Turkey's increasing liquefied natural gas (LNG) demand. This model demonstrates a number of alternative policy options for LNG supply. Furthermore, the authors consider that increasing the proportion of LNG in the overall gas supply will contribute to the aim of improving Turkey's level of energy security.

13/01399 Modelling liquefied-natural-gas processes using highly accurate property modelsDauber, F. and Span, R. *Applied Energy*, 2012, 97, 822–827.

Accurate simulations are important for efficient design and operation of a process. Therefore, a precise representation of thermophysical properties using an adequate property model is necessary. The GERG-2008 by Kunz and Wagner is the new reference equation of state for natural gases consisting of up to 21 specific compounds. It describes the gas and liquid phase as well as the super-critical region and the vapour–liquid equilibrium. In order to model liquefied natural gas (LNG) processes with the highest accuracy available, software available for the new equation is implemented into various common simulation tools. To ensure stable and consistent simulations, the GERG-2008 property package has been developed, which meets the CAPE-OPEN standard. The influence of property models on the simulation of the most important processes of the LNG value chain is investigated. Results show the expected advantages in accuracy for simulations using the new property model.

13/01400 Retrofit design of a boil-off gas handling process in liquefied natural gas receiving terminalsPark, C. *et al. Energy*, 2012, 44, (1), 69–78.

Generation of boil-off gas (BOG) in liquefied natural gas (LNG) receiving terminals considerably affects operating costs and the safety of the facility. For the above reasons, a proper BOG handling process is a major determinant in the design of a LNG receiving terminal. This study proposes the concept of a retrofit design for a BOG the handling process using a fundamental analysis. A base design was determined for a minimum send-out case in which the BOG handling becomes the most difficult. In the proposed design, the cryogenic energy of the LNG stream is used to cool other streams inside the process. It leads to a reduction in the operating costs of the compressors in the BOG handling process. Design variables of the retrofit design were optimized with non-linear programming to maximize profitability. Optimization results were compared with the base design to show the effect of the proposed design. The proposed design provides a 22.7% energy saving ratio and a 0.176 year payback period.

Hydrogen generation and storage

13/01401 An experimental investigation to improve the hydrogen production by water photoelectrolysis when cyanin-chloride is used as sensitizerRossi, F. and Nicolini, A. *Applied Energy*, 2012, 97, 763–770.

This paper deals with an experimental investigation to improve the hydrogen production by water photoelectrolysis. An experimental facility was built: it is mainly constituted by a solar simulator, the photoelectrolytic cell, the electric power supply system and a recirculating and gas sampling hydraulic circuit. Titanium dioxide was chosen as catalyst because of its good photocatalytic efficiency and its high stability to pH variations in watery solutions. Cyanin chloride was tested as sensitizer: it is a flavonoid, an organic dye, which gives to the watery solution better solar radiation absorption performances. The catalyst and the sensitizer were deposited on the cathode surface. A sacrificial reducing agent, ethylenediaminetetraacetic acid, was also introduced in the solution to reduce the sensitizer and restore the original conditions. Different radiation power and electrolytic pH conditions were tested in order to verify the proposed arrangements. Results showed a growing in the hydrogen production by the proposed photoelectrolytic arrangements with respect to the performance of a simple electrolysis. Thus, the obtained results showed that this technology has good possibilities of improvement and interesting perspective of future development.

13/01402 CoO nanocrystals as a highly active catalyst for the generation of hydrogen from hydrolysis of sodium borohydride

Lu, A. *et al. Journal of Power Sources*, 2012, 220, 391–398.
The authors report the excellent catalytic performance of CoO nanocrystals on the catalytic hydrolysis of alkaline NaBH₄ solutions. CoO nanocrystals with octahedral and near-spherical shapes are synthesized using a facile chemical solution method that employed cobalt acetate tetrahydrate as metal precursor in the presence of oleylamine. The octahedral CoO nanocrystals typically have a size of 40–50 nm, while the near-spherical nanocrystals have a size varying from 8 to 13 nm. Both of them have a face centred cubic (fcc) crystalline phase. Catalytic tests show that the as-synthesized CoO nanocrystals exhibit very high activities for the H₂ generation from the hydrolysis of alkaline NaBH₄ solutions. The maximum hydrogen generation rate of the as-synthesized CoO nanocrystals exceeds most reported values of transition metal or noble metal contained catalysts performed in alkaline NaBH₄ solutions. The influences of shape on the catalytic behaviours of as-synthesized CoO nanocrystals are also compared and analysed. The results presented in this study indicate that CoO nanocrystals are a promising candidate to replace noble metal catalysts in the H₂ generation from the hydrolysis of borohydrides.

13/01403 Dynamic process control and monitoring of novel S³RS based hydrogen cooling system

Biswal, G. R. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 162–172.
Hydrogen gas is circulated in a closed loop within the generators to remove heat from its active parts. Then it is cooled by gas-to-water heat exchangers that are part of the stator frame. Faster heat dissipation of generators in power plant call for hydrogen cooling system (HCS) at generating end. Purity in hydrogen (H₂) improves its ability to dissipate heat within generators. Therefore, there is an essential requirement of a highly reliable and efficient process control and monitoring system of H₂ cooling. This paper presents development and implementation of supervisory control and data acquisition (SCADA) based process control and monitoring system. It proposes a novel six-stage standby redundant structured (S³RS) HCS for generators cooling in typical thermal power plant. The entire process control and monitoring of HCS has been developed and simulated on RSVIEWSE, a real-time industrial automation platform by Allen Bradley–Rockwell Automation. And, the system reliability of proposed S³RS process model is implemented using MATLAB. This process model satisfies the requirement of IEEE Std. C37.1TM-2007, the standard for SCADA and automation systems. It also follows IEEE Std. 493TM-1997, the standard for design of reliable industrial and commercial power systems, and IEC 60034-3, the standard for rotating electrical machines.

13/01404 Efficiency comparison of various design schemes for copper–chlorine (Cu–Cl) hydrogen production processes using Aspen Plus software

Orhan, M. F. *et al. Energy Conversion and Management*, 2012, 63, 70–86.
In this study, simulation models are developed to analyse, design and optimize the Cu–Cl cycles using the Aspen PlusTM chemical process simulation package. Energy, exergy and yield effectiveness of the process, based on three, four and five-step cycles, is examined. The thermal efficiency of the five-step thermochemical process is calculated as 44%, of the four-step process is 43% and of the three-step process is 41%, based on the lower heating value of hydrogen. Sensitivity analyses are performed to study the effects of various operating parameters on the efficiency and yield. A parametric study is conducted and possible efficiency improvements are discussed. Furthermore, new system

configurations for the Cu–Cl cycle are developed for performance improvement in this study. Various design schemes, based on three, four and five-step Cu–Cl cycles, are analysed and compared. Also, recommendations for implementation of these new design schemes are presented in detail.

13/01405 Enhanced photo-H₂ production by *Rhodospseudomonas faecalis* RLD-53 immobilization on activated carbon fibers

Xie, G.-J. *et al. Biomass and Bioenergy*, 2012, 44, 122–129.
Activated carbon fibres (ACFs) were firstly applied as fluidized solid carrier to immobilize photo-fermentative bacteria (PFB) for H₂ production in batch culture. The observations by scanning electronic microscopy (SEM) demonstrated the close interaction between ACFs and PFB. The amount of immobilized bacteria and the performance of H₂ production were strongly affected by specific surface area, length and amount of ACFs, respectively. Large specific surface area provided more surface attachment sites and more PFB were immobilized. ACFs with proper length avoided intertwining with each other and better fluidized during reactor operation. Excessive amount of ACFs not only limited the light conversion efficiency, but also increased biofilm detachment, resulting in low H₂ yield. The maximum yield (3.08 mol H₂ mol⁻¹ acetate) and rate (32.85 ml l⁻¹ h⁻¹) of H₂ production were obtained, using specific surface area (1500 m² g⁻¹), length (1 mm) and amount (0.8 g l⁻¹) of ACFs. Compared with the conventional solid carriers, ACFs were effective solid carriers to immobilize PFB for improving H₂ production, due to bacteria immobilized on the external surface of fluidized ACFs and formed a layer of dense biofilm.

13/01406 Improved hydrogen production from water splitting using TiO₂–ZnO mixed oxides photocatalysts

Pérez-Larios, A. *et al. Fuel*, 2012, 100, 139–143.
TiO₂–ZnO mixed oxides (1.0, 3.0, 5.0 and 10.0 wt% Zn) photoconductors were prepared by the sol–gel method and used for the H₂ production from water splitting. The solids were characterized by nitrogen physisorption, XRD, RAMAN, EDS, UV–Vis and XPS spectroscopy. High specific surface areas (85–159 m²/g) were obtained in all the mixed oxides compared to the bare TiO₂ sample (64 m²/g). XRD and Raman spectra show that anatase is the predominant crystalline phase on the TiO₂–ZnO solids. The band gap energy of the solids is in the interval from 3.05 to 3.12 eV which are in the same order than TiO₂ (3.2 eV). These solids were proved in the photocatalytic water splitting and resulted six times more active (1300 μmol/h) than the reference TiO₂ (190 μmol/h) semiconductor.

13/01407 Preparation and characterization of hydro-reactive Mg–Al mechanical alloy materials for hydrogen production in seawater

Zou, M.-S. *et al. Journal of Power Sources*, 2012, 219, 60–64.
Hydro-reactive Mg–Al mechanical alloy materials are prepared by high-energy milling. Scanning electron microscopy (SEM), thermogravimetric (TG) and powder X-ray diffraction (XRD) techniques are used to characterize the materials. Their hydrolysis properties are studied in seawater by measuring the hydrogen volume produced and by calculating the rate of hydrogen evolution. The collected reaction products are analysed after hydrolysis. The experimental results show that there are the squashed, overlapped and fined steps for metal powder in the milling progress. As the milling time increases from 0 to 4 h, the initial oxidation temperature of Mg–Al mechanical alloy materials first increases, and then decreases. An increase in milling time is found to improve the hydrogen generation rate and the hydrogen yield during hydrolysis. When the milling time reaches 4 h, the hydrolysis reaction is immediately noticeable, generating 397 mL (min g)⁻¹ of hydrogen within the first second minutes, and the total hydrogen evolution is 950 mL of hydrogen, or 97.1% of the theoretical yield.

13/01408 Production of hydrogen and sulfur from hydrogen sulfide assisted by nonthermal plasma

Reddy, E. L. *et al. Applied Energy*, 2012, 95, 87–92.
Hydrogen production by non-thermal plasma (NTP) assisted direct decomposition of hydrogen sulfide was studied in a dielectric barrier discharge (DBD) reactor operated under ambient conditions. It may be concluded that NTP is effective in direct decomposition of H₂S into H₂ and S. Changing ground electrode material from silver paste to either copper wire or aluminium foil only increased the energy demand, but did not show any significant improvement in conversion. Influence of various parameters like ground electrode, discharge gap, residence time and H₂S concentration were studied to achieve hydrogen production under energetically feasible conditions. It has been observed that H₂S conversion into H₂ and S may be efficient at high residence time and low concentrations. By optimizing the reaction conditions, H₂ production may be produced at 160 kJ/mol (~1.6 eV/H₂) that is less than the energy demand in steam methane reforming (354 kJ/mol H₂ or 3.7 eV/H₂).

13/01409 Strategies for improving biological hydrogen production

Hallenbeck, P. C. *et al. Bioresource Technology*, 2012, 110, 1–9.
Biological hydrogen production presents a possible avenue for the large-scale sustainable generation of hydrogen needed to fuel a future hydrogen economy. Amongst the possible approaches that are under active investigation and that will be briefly discussed; biophotolysis, photofermentation, microbial electrolysis, and dark fermentation, dark fermentation has the additional advantages of largely relying on already developed bioprocess technology and of potentially using various waste streams as feedstock. However, the major roadblock to developing a practical process has been the low yields, typically around 25%, well below those achievable for the production of other biofuels from the same feedstocks. Moreover, low yields also lead to the generation of side products whose large scale production would generate a waste disposal problem. Here recent attempts to overcome these barriers are reviewed and recent progress in efforts to increase hydrogen yields through physiological manipulation, metabolic engineering and the use of two-stage systems are described.

13/01410 The study of preparation and photoelectrical properties of chemical bath deposited Zn, Sb and Ni-doped CuInS₂ films for hydrogen production

Garskaite, E. *et al. Solar Energy*, 2012, 86, (9), 2584–2591.
Pure and Zn, Sb, Ni-doped CuInS₂ films were prepared by chemical bath deposition method. Structural, morphological, optical, and photoelectrochemical properties of the as-grown films were investigated. X-ray diffraction analysis revealed that films consisted of the tetragonal CuInS₂ phase. The energy band gaps and carrier densities of these samples were in the ranges of 1.48–1.54 eV and 2.38×10^{18} – 9.38×10^{19} , respectively. The maximum photocurrent density of samples with a potential of –1.0 V versus a Pt electrode was found to be –8.58 mA/cm² with the largest hydrogen production capability of 33.26 μmol/cm² under illumination using a 300 W Xe lamp system.

13/01411 Thermodynamic analysis of ethanol reforming for hydrogen production

Sun, S. *et al. Energy*, 2012, 44, (1), 911–924.
This work presents the simulated equilibrium compositions of ethanol steam reforming (SR), partial oxidation (POX) and auto-thermal reforming (ATR) at a large temperature range, steam-to-ethanol and oxygen-to-ethanol molar ratios. The simulation work shows that the moles of hydrogen yield per mole ethanol are of this order: SR > ATR > POX. The results are compared with other simulation works and fitted models, which show that all the simulation results obtained with different methods agree well with each other. And the fitted models are in highly consistency with very small deviations. Moreover, the thermal-neutral point in corresponding to temperature, steam-to-ethanol and oxygen-to-ethanol mole ratios of ethanol ATR is estimated. The result shows that with the increasing of oxygen-to-ethanol mole ratio, the T-N point moves to higher temperatures; with the increasing of steam-to-ethanol mole ratio, the T-N point moves to lower temperatures. Furthermore, the energy exchanges of the reforming process and the whole process and the thermal efficiencies are also analysed in the present work and that the energy demands and generated in the whole process are greater than the reforming process can be obtained. Finally, the optimum reaction conditions are selected.

13/01412 Ti_{12.5}Zr₂₁V₁₀Cr_{8.5}Mn_xCo_{1.5}Ni_{46.5-x} AB₂-type metal hydride alloys for electrochemical storage application: Part 2. Hydrogen storage and electrochemical properties

Young, K. *et al. Journal of Power Sources*, 2012, 218, 487–494.
In this paper, the hydrogen gas charging and electrochemical properties of a series of AB₂-based metal alloys (Ti_{12.5}Zr₂₁V₁₀Cr_{8.5}Mn_xCo_{1.5}Ni_{46.5-x}) designed to have different fractions of Zr–Ni-type secondary phases by varying the Mn/Ni-content were studied to establish correlations of these properties with abundances of the secondary phases. In the gas charging, the general trend of pressure–concentration–temperature slope factor and hysteresis is to diminish with increase in the Zr₇Ni₁₀ phase abundance; the trend of reversible hydrogen storage capacity is to increase as the TiNi-derived AB phase abundance increases. As for the electrochemical properties, the number of activation cycles needed to achieve a given percentage of capacity and power decreases with increase in the total amount of secondary phases. Trends of changes in both the total and reversible capacities follow that in AB phase abundance; the evolution of high-rate dischargeability, bulk diffusion, and surface exchange current is similar to that of Zr₇Ni₁₀ phase abundance – increase in the beginning and decrease afterward as the Mn-content in the alloy increases. Other properties, such as metal–hydrogen bond strength and maximum gaseous phase storage capacity, are predominately dependent on the alloys' composition, i.e. the Mn/Ni ratio.

04 BY-PRODUCTS RELATED TO FUELS

13/01413 Application of zeolitic materials prepared from fly ash to water vapor adsorption for solar cooling

Karamanis, D. and Vardoulakis, E. *Applied Energy*, 2012, 97, 334–339.
The water vapour adsorption properties of raw and hydrothermally treated fly ashes with NaOH and their application prospect as evaporative coolers of roof surfaces were studied. Initially, samples were characterized through techniques like elemental analysis, X-ray diffraction, thermogravimetry, reflectance measurements and water vapour adsorption isotherms. Moreover, the water adsorption properties and the associated temperature variations were determined in a specific wind tunnel with controllable environmental conditions. The adsorption isotherms for fly ash were of type III indicating hydrophobic material with low water vapour adsorption. The hydrothermal treatment in an alkaline solution transformed the fly ash in hydrophilic material of type IV. Moreover, the treated samples were capable of lowering their surface temperatures due to water evaporation and the release of the latent heat. The maximum difference of temperature increase under simulated solar irradiation was observed between the treated fly ash and the concrete with values of 5.0, 5.4 and 7.5 °C for the surface, middle and bottom position, respectively. The results indicate that the zeolitic materials prepared from the fly ash samples have a significant potential for solar cooling applications.

13/01414 Evaluation of bituminous wastes as coal fluidity enhancers

Fernández, A. M. *et al. Fuel*, 2012, 101, 45–52.
The ability of two bituminous wastes to modify the plastic properties of a coal has been studied and compared with that of a commercial coal-tar pitch. For the study three coals covering the rank normally used in metallurgical coke production were chosen. The bituminous wastes were obtained from the benzol distillation tower of the by-products section of a coking plant. Thermogravimetry was used to determine the amount of volatile matter that evolves at different temperature ranges. The differences observed in the behaviour of the wastes were explained by examining the composition of the toluene soluble fraction with the aid of gas and liquid chromatography and infrared spectroscopy. It was found that irrespective of softening point, ash content and solubility in organic solvents, the composition of the additives has a decisive influence on the modification of coal plastic stage by bituminous wastes.

13/01415 Prediction of ash slagging propensity in a pulverized coal combustion furnace

Degereji, M. U. *et al. Fuel*, 2012, 101, 171–178.
The slagging of heat transfer surfaces during the combustion of pulverized coal in power stations is a major problem as power generators strive to improve the efficiency of their plants. In this paper, a numerical model to predict ash deposition rates in boilers has been developed. The deposition model is based on the sticking tendency of ash particles on impaction on boiler walls. A numerical slagging index (NSI) that correlates with the practical performance of different coals has also been developed. The index is based on ash viscosity, ash fusibility and the ash loading. Experimental data from the Australian Coal Industries Research Laboratories (ACIRL) furnace have been used to validate the models. The predicted results from the ash deposition model on four different coals are in good agreement with the experimental measurements, and the new slagging index has successfully ranked the investigated coals according to their field performance. In general, the predicted results from both the ash deposition model and the new NSI are in good agreement with the experimental data.

13/01416 Prediction of the bottom ash formed in a coal-fired power plant using artificial neural networks

Bekat, T. *et al. Energy*, 2012, 45, (1), 882–887.
The amount of bottom ash formed in a pulverized coal-fired power plant was predicted by artificial neural network modelling using a year's operating data of the plant and the properties of the coals processed. The model output was defined as the ratio of amount of bottom ash produced to amount of coal burned (bottom ash/coal burned). The input parameters were the moisture contents, ash contents and lower heating values of the coals. The total 653 data were divided into two groups for the training (90% of the data) and the testing (10% of the data) of the network. A three-layer, feed-forward type network architecture with back-propagation learning was used in the modelling study. The activation function was sigmoid function. The best prediction performance was obtained for a one hidden layer network with 29 neurons. The learning rate and the tolerance value were 0.2 and 0.05, respectively. R² (coefficient of determination) values between the actual (bottom ash/coal burned) ratios and the model

predictions were 0.988 for the training set and 0.984 for the testing set. In addition, the sensitivity analysis indicated that the ash content of coals was the most effective parameter for the prediction of the ratio of bottom ash to coal burned.

13/01417 Rapid molecular screening of black carbon (biochar) thermosequences obtained from chestnut wood and rice straw: a pyrolysis-GC/MS study

Kaal, J. *et al. Biomass and Bioenergy*, 2012, 45, 115–129.

Rice straw and chestnut wood were heated between 200 and 1000 °C (T_{CHAR}) to produce Black C 'thermosequences'. The molecular properties of the charred residues were assessed by pyrolysis-GC/MS to investigate the relation between charring intensity and pyrolysis fingerprint. Samples obtained at $T_{CHAR} > 500$ °C (wood) or > 700 °C (straw) gave low quality pyrograms and poor reproducibility because of high thermal stability, but pyrolysis-GC/MS allowed to track the thermal degradation of the main biocomponents (polysaccharides, lignin, methylene chain-based aliphatics, triterpenoids, chlorophyll and proteins) in the lower temperature range, mostly occurring between T_{CHAR} 250 and 500 °C. With increasing T_{CHAR} , the charred residues of these biocomponents lose characteristic functional groups, aromatise and finally condense into non-pyrolysable biomass. The proportions of the pyrolysis products of unspecific origin (benzene, toluene, PAHs, etc.), increase with charring intensity, while the ratios that reflect the abundance of alkyl cross-linkages between aromatic moieties (e.g. benzene/toluene, naphthalene/alkylnaphthalene) decrease. These results provide the guidelines to using pyrolysis-GC/MS for the molecular characterization of different components in Black C and biochar, which is an important parameter for predicting Black C/biochar behaviour in soil. Results are consistent with earlier studies of these samples using the BPCA (benzenepolycarboxylic acid) method and the ring current-induced ^{13}C benzene chemical shift NMR (nuclear magnetic resonance) approach. Pyrolysis-GC/MS provides more information on molecular structures in the low temperature range ($T_{CHAR} \leq 500$ °C) while the BPCA and NMR ring current methods provide more reliable estimations of charring intensity, especially at higher temperatures ($T_{CHAR} \geq 500$ °C).

13/01418 Soot formation in high pressure laminar diffusion flames

Karatas, A. E. and Gülder, Ö. L. *Progress in Energy and Combustion Science*, 2012, 38, (6), 818–845.

The details of the chemical and physical mechanisms of the soot formation process in combustion remain uncertain due to the highly complex nature of hydrocarbon flames, and only a few principles are firmly established, mostly for atmospheric conditions. In spite of the fact that most combustion devices used for transportation operate at very high pressures (e.g. aircraft gas turbines up to 40 atm, diesel engines exceeding 100 atm), understanding of soot formation at these pressures is not at a desirable level, and there is a fundamental lack of experimental data and complementary predictive models. The focus of this review is to assess the experimental results available from laminar co-flow diffusion flames burning at elevated pressures. First, a brief review of soot formation mechanisms in diffusion flames is presented. This is followed by an assessment of soot diagnostics techniques, both intrusive and non-intrusive, most commonly used in soot experiments including the laser-induced incandescence. Then the experimental results of soot measurements done at elevated pressures in diffusion flames are reviewed and critically assessed. Soot studies in shock tubes and in premixed flames are not covered. Smoke point fuel mass flow rate is revisited, and shortcomings in recent measurements are pointed. The basic requirements for tractable and comparable measurements as a function of pressure are summarized. Most recent studies at high pressures with aliphatic gaseous fuels show that the soot yield displays a unified behaviour with reduced pressure. The maximum soot yield seems to reach a plateau asymptotically as the pressure exceeds the critical pressure of the fuel. Lack of experimental data on the sensitivity of soot morphology to pressure is emphasized. A short summary of efforts in the literature on the numerical simulation of soot formation in diffusion flames at high pressures is the last section of the paper.

13/01419 Synthesis of nano-zeolite from coal fly ash and its potential for nutrient sequestration from anaerobically digested swine wastewater

Chen, X. *et al. Bioresource Technology*, 2012, 110, 79–85.

The treatment of anaerobically digested swine wastewater (ADSW) is problematic due to its high nutrient concentration. This study investigated the simultaneous sequestration of ammonium (N) and phosphate (P) from ADSW using nano-zeolites synthesized from fly ash (ZFA). The nanometer-scale crystalline structures plentiful of zeolite-NaP1 coating on ZFA particle increased the levels of specific surface area and cation exchange capacity at times of 40 and 104, compared to raw fly ash. Kinetic N and P sorption experiments with ZFA were well described by both the Langmuir and Freundlich models, suggesting the co-existence of homogeneous and hetero-

geneous sorption mechanisms. N and P removal efficiencies ranged from 41% to 95% and 75% to 98%, respectively, across a range of ZFA doses (from 0.25 to 8 g/100 ml). Collectively, application of the laboratory-synthesized ZFA can alleviate the nutrient loads in ADSW and therefore modify the ratio of N:P in wastewater beneficial for subsequent biological treatment.

05 NUCLEAR FUELS

Scientific, technical

13/01420 An optimal hybrid model for atomic power generation prediction in Japan

Li, G.-D. *et al. Energy*, 2012, 45, (1), 655–661.

The grey model GM(1,1), which is based on grey system theory, has become a powerful tool for the prediction problems in power systems. However, the prediction accuracy of grey model is unsatisfying when original data set shows great randomness. In this paper, in order to improve the prediction capability of grey model, the exponential smoothing (ES) method is integrated into GM(1,1) through the preprocessing for original data set. The authors call the proposed model ESGM(1,1). The Taylor approximation method is then presented to find the optimal coefficient values of ESGM(1,1). The improved model is defined as T-ESGM(1,1). Finally, Markov chain model is applied to T-ESGM(1,1) for achieving the high prediction accuracy. The authors call the proposed model MC-T-ESGM(1,1). From the results of accuracy comparison, the proposed models obtained satisfactory prediction results. Future work will focus on applying the proposed model to the prediction problem of hydro and thermal power generation in power systems.

13/01421 Analytic study of radiation shielding using proton beams in a fusion reactor and a spherical isotropic power reactor (SIPR)

Woo, T. H. *Annals of Nuclear Energy*, 2012, 47, 110–114.

The radiation shielding of the spherical geometry is analysed. The proposed power plant, spherical isotropic power reactor (SIPR), is compared with the nuclear fusion reactor, ARIES-ST. Two cases focus on the economic matter by reducing the thickness in reactor vessel. The reactor vessel is examined for the thickness in the radiation shielding, which can be calculated by the Monte Carlo simulation code system stopping and range of ions in matter-2010 (SRIM-2010), using proton beams. The nanoscale behaviour of the nuclear fuel molecule is analysed using SRIM-2010 computer package. The radius in cylindrical core is varied from 2.190 to 6.675 m. It is 3.638 m in the spherical core. The results show highly enhanced shielding operations. It is proposed to reduce the thickness of the reactor core vessel.

13/01422 Effect of void-fraction on characteristics of several thorium fuel cycles in BWR

Waris, A. *et al. Energy Conversion and Management*, 2012, 63, 11–16.

Study on effect of void-fraction on characteristics of several thorium fuel cycles in boiling water reactor (BWR) has been carried out. Four fuel cycle scenarios are evaluated and the comparison with once-through-cycle BWR was also conducted. The 1367 nuclides have been employed in the time independent burn-up calculation scheme where 129 of them are heavy metals (HMs). The burn-up code was facilitated with the calculation method for determining the required ^{233}U concentration for criticality of the system inherently. The code was coupled with SRAC 2002 cell calculation code to compose a time independent-cell burn-up code. In the cell calculation, 26 HMs, 66 fission products (FPs) and one pseudo FP have been utilized. The JENDL 3.2 library has been employed in this study. The results show that the profile of the required ^{233}U concentration for criticality depends on the neutron spectra and the microscopic cross-section. However, the profile of the conversion ratio likely depends on the number density of heavy nuclides.

13/01423 Fuel residence time in BWRs with nitride fuels

Zakova, J. and Wallenius, J. *Annals of Nuclear Energy*, 2012, 47, 182–191.

This paper presents a neutronics study of a BWR core with uranium nitride fuels. Replacing the standard UO_2 fuel with UN or UN-ZrO₂ allows for a higher uranium content, which leads to an increase of the in-core fuel residence time. With the nitride fuels, the total void worth increases and the efficiency of the control rods and burnable poison

deteriorates. Taking into account the higher amount of burnable poison needed at the beginning of life, the in-core fuel residence time increases by about 1.4 year comparing to UO_2 fuel with the same enrichment. This implies 1.4% higher availability of the plant and it is therefore of economic interest to the nuclear power plant operators. A similar increase of the fuel in-core lifetime in a UO_2 core could be reached by an increase of the average enrichment of the oxide fuel by roughly 1%.

13/01424 LIFE hybrid reactor as reactor grade plutonium burner

Sahin, S. *et al. Energy Conversion and Management*, 2012, 63, 44–50. The early version of the conceptual modified design of the laser inertial confinement fusion fission engine (LIFE) engine consists of a spherical fusion chamber of 5 m diameter, surrounded by a multi-layered blanket. The first wall is made of 2 cm thick ODS and followed by a $\text{Li}_7\text{Pb}_{83}$ zone (2 cm), acting as neutron multiplier, tritium breeding and front coolant zone. It is separated by an ODS layer (2 cm) from the FLIBE molten salt zone (50 cm), containing fissionable fuel. A third ODS layer (2 cm) separates the molten salt zone on the right side from the graphite reflector (30 cm). Calculations have been conducted for a constant fusion driver power of 500 MW_{th} in $\text{S}_8\text{-P}_3$ approximation using 238-neutron groups. Reactor grade (RG) plutonium carbide fuel in form of TRISO particles with volume fractions of 2%, 3%, 4%, 5% and 6% have been dispersed homogeneously in the FLIBE coolant. Tritium breeding ratio (TBR) values per incident fusion neutron for the above cited cases start with TBR = 1.35, 1.52, 1.73, 2.02 and 2.47, respectively. With the depletion of fissionable RG-Pu isotopes, TBR decreases gradually. At startup, higher fissionable fuel content in the molten salt leads to higher blanket energy multiplication, namely $M_0 = 3.8, 5.5, 7.7, 10.8$ and 15.4 with 2%, 3%, 4%, 5% and 6% TRISO volume fraction, respectively. Calculations have led to very high burn up values ($>400,000 \text{ MD.D/MT}$). TRISO particles can withstand such high burn ups. Such high burn ups would lead to drastic reduction of final nuclear waste per unit energy production.

13/01425 Modeling of pipe break accident in a district heating system using RELAP5 computer code

Kaliatka, A. and Valincius, M. *Energy*, 2012, 44, (1), 813–819. Reliability of a district heat supply system is a very important factor. However, accidents are inevitable and they occur due to various reasons, therefore it is necessary to have possibility to evaluate the consequences of possible accidents. This paper demonstrated the capabilities of developed district heating network model (for RELAP5 code) to analyse dynamic processes taking place in the network. A pipe break in a water supply line accident scenario in Kaunas city (Lithuania) heating network is presented in this paper. The results of this case study were used to demonstrate a possibility of the break location identification by pressure decrease propagation in the network.

13/01426 Radiation distribution through serpentine concrete using local materials and its application as a reactor biological shield

Kansouh, W. A. *Annals of Nuclear Energy*, 2012, 47, 258–263. In the present work attempt has been made to estimate the shielding parameters of the new serpentine concrete (density = 2.4 g/cm^3) using local materials on the shielding parameters for two types of heat resistant concretes, namely hematite–serpentine (density = 2.5 g/cm^3) and ilmenite–limonite (density = 2.9 g/cm^3). Shielding parameters for ordinary concrete (density = 2.3 g/cm^3) were also discussed. These parameters were determined experimentally for serpentine concrete and compared with previously published values for other concretes, which had also been obtained using local materials. The leakage spectra of reactor fast neutrons and total gamma photon beams from cylindrical samples of these concrete shields were also investigated using a collimated beam from ET-RR-1 reactor. A neutron–gamma spectrometer was used in order to obtain pulse height spectra of reactor fast neutrons and the total gamma rays leakage through the investigated concrete samples. These spectra were utilized to obtain the energy spectra required in these investigations. Removal cross-section $\Sigma_R(E_n)$ and linear attenuation coefficient $\mu(E_\gamma)$ for reactor fast neutrons and total gamma rays and their relative coefficients were evaluated and presented. Measured results were compared with those previously measured for other concretes. The results show that ilmenite–limonite concrete is a better reactor biological shield than the other three concretes. Serpentine concrete under investigation is a better reactor fast neutrons shield than ordinary and hematite–serpentine concretes. Serpentine concrete has a lower attenuation properties than the other three concretes as a reactor total gamma rays shields.

13/01427 Superior techniques for disposal of highly radioactive waste (HLW)

Pusch, R. and Weston, R. *Progress in Nuclear Energy*, 2012, 59, 75–85.

The Swedish Nuclear Fuel and Waste Company (SKB) has recently worked out a concept, KBS-3V, for disposal of highly radioactive waste in the form of spent reactor fuel, and asked for the government's approval and licensing. It implies blasting of tunnels at about 400 m depth and boring of large-diameter canister deposition holes extending vertically from the tunnel floor. The rock stresses will be critically high in the construction phase and lead to failure by spalling when the heat pulse from the canisters evolves. The canisters will be surrounded by dense expansive 'buffer' clay for minimizing groundwater flow around and along them but the long-term performance of either of them is not adequately proven and the placement is impractical and risky. Four major changes of the concept would make it satisfactory. One involves reorientation of the deposition holes from vertical to 45° inclination in two directions for reducing the risk of rock failure. A second is to prepare ready-made stiff units of 'supercontainers' with highly compacted blocks of clay tightly surrounding the canisters for simpler and safer installation of clay blocks and canisters. A third is to surround the supercontainers by clay mud that provides the dense buffer with water from start and supports the surrounding rock when the thermal pulse begins to raise the rock stresses. A fourth is to replace the proposed smectite-rich buffer by clay with higher chemical stability and lower but sufficient expandability. A possible fifth change can be to manufacture homogeneous copper canisters of HIPOW type, which would radically reduce the risk of contamination of groundwater by released radionuclides.

Economics, policy, supplies, forecasts

13/01428 Benefits and cost implications from integrating small flexible nuclear reactors with off-shore wind farms in a virtual power plant

Shropshire, D. *et al. Energy Policy*, 2012, 46, 558–573. Nuclear power currently supports the goals of the European Union low-carbon society by being a dependable source of energy, while emitting no CO_2 . In the future, more flexible nuclear systems could enable wind to achieve a 50% share of the renewable contribution to the energy mix. Small and medium-sized reactors (SMRs) could provide firming power generation to back-up the supply from renewable resources and follow-load. This study involves the hypothetical combination of an off-shore wind farm and a SMR, operated together as a virtual power plant (VPP). Results using wind data from the North Sea indicate that the combination results in 80% less wind power variation to the grid, effectively creating a virtual baseload power plant. This gain comes at the loss of 30% SMR capacity utilization. The research identified that the reduction of 1000 MW off-shore wind farm variability was best achieved with 700 MW SMRs using 100 MW modules. In demand-following mode the VPP could manoeuvre output to improve synchronization with demand by 60–70% over a wind-only system. Power variability was indifferent to the SMR module size. The VPP could not reduce 100% of the wind variation, as additional balancing measures (e.g. smart grid, storage, and hybrid-nuclear systems) are still needed.

13/01429 Commercial utilization of weapon grade plutonium as TRISO fuel in conventional CANDU reactors

Sahin, S. *et al. Energy Conversion and Management*, 2012, 63, 17–24. Large quantities of weapon grade (WG) plutonium have been accumulated in the nuclear warheads. Plutonium and heavy water moderator can give a good combination with respect to neutron economy. TRISO type fuel can withstand very high fuel burn up levels. The paper investigates the prospects of utilization of TRISO fuel made of WG-plutonium in CANDU reactors. Three different fuel compositions have been investigated: (1) 90% ThC + 10% PuC, (2) 70% ThC + 30% PuC and (3) 50% ThC + 50% PuC. The temporal variation of the criticality k_∞ and the burn-up values of the reactor have been calculated by full power operation up to 17 years. Calculated startup criticalities for these fuel modes are $k_{\infty,0} = 1.6403, 1.7228$ and 1.7662 , respectively. Attainable burn up values and reactor operation times without new fuel charge will be 94,700, 265,000 and 425,000 MW.D/MT and along with continuous operation periods of $\sim 3.5, 10$ and 17 years, respectively, for the corresponding modes. These high burn ups would reduce fuel fabrication costs and nuclear waste mass for final disposal per unit energy drastically.

13/01430 Conceptual design for a small modular district heating reactor for Mongolia

Sambu, O. and Obara, T. *Annals of Nuclear Energy*, 2012, 47, 210–215. The energy demand in Mongolia is expected to increase in the near future. The purpose of the present study was to design a small, modular district heating reactor with passive safety features for long core life to

meet the country's expected energy demand. The design concept was based on the advanced and well-proven technology of the high temperature gas-cooled reactor (HTGR) idea. The reactor size was roughly estimated without any active cooling system to remove the decay heat, and the optimal core dimensions chosen were 8 m diameter and 8 m height with 330 MW_{th} of power. Fundamental analyses of the reactor for criticality and burn-up were performed by using continuous energy Monte Carlo code MVP 2.0, and the proposed reactor with 20 wt% of uranium enrichment can be critical around 16 years. The initial effective neutron multiplication factor can be suppressed to 1.1351 when there are nine burnable poison (BP) rods with 12 wt% of boron carbide in B₄C/C composite and 10 wt% of ¹⁰B per assembly.

13/01431 Cost probability analysis of reprocessing spent nuclear fuel in the US

Recktenwald, G. D. and Deinert, M. R. *Energy Economics*, 2012, 34, (6), 1873–1881.

The methods by which nuclear power's radioactive signature could be reduced typically require the reprocessing of spent nuclear fuel. However, economic assessments of the costs that are associated with doing this are subject to a high degree of uncertainty. The authors present a probabilistic analysis of the costs to build, operate and decommission the facilities that would be required to reprocess all US spent nuclear fuel generated over 100-year time frame, starting from a 2010 power production rate. The analysis suggests a total life-cycle cost of 2.11 ± 0.26 mills/kWh, with a 90% and 99% confidence that the overall cost would remain below 2.45 and 2.75 mills/kWh respectively. The most significant effects on cost come from the efficiency of the reactor fleet and the growth rate of nuclear power. The analysis shows that discounting results in life-cycle costs decreasing as recycling is delayed. However the costs to store spent fuel closely counter the effect of discounting when an intergenerational discount rate is used.

13/01432 Decarbonizing the electric sector: combining renewable and nuclear energy using thermal storage

Denholm, P. *et al. Energy Policy*, 2012, 44, 301–311.

Both renewable and nuclear energy can provide significant contributions to decarbonizing the electric sector. However, a grid employing large amounts of wind and solar energy requires the balance of the system to be highly flexible to respond to the increased variability of the net load. This makes deployment of conventional nuclear power challenging both due to the technical challenges of plant cycling and economic limits of reduced capacity factor. In the USA nuclear power plants generally provide constant, base load power and are most economic when operated at constant power levels. Operating nuclear power plants in load-following modes decreases the plants' annual energy output and increases the levelized cost of energy, decreasing economic competitiveness. One possible solution is to couple thermal energy storage to nuclear power plants. This would enable the reactor to remain at nearly constant output, while cycling the electrical generator in response to the variability of the net load. This paper conceptually explores combinations of wind, solar, and nuclear that can provide a large fraction of a system's electricity, assuming the use of thermal energy storage that would allow nuclear power to provide load following and cycling duty while operating at a constant reactor power output.

13/01433 Dynamical modeling investigation for economy of nuclear power plants (NPPs) in global nuclear energy market

Woo, T. H. *International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 369–374.

Non-linear dynamical analysis for the global nuclear energy market is investigated. Currently, the market means a different characteristics comparing to the past situation which had been done before two severe accidents as the Three Mile Island nuclear power plant (NPP) accident in the USA and the Chernobyl NPP disaster in the former Soviet Union. For the nuclear-related facility, the environmental and safety aspects are the important issues of the analysis. Fundamentally, the economic factor is still a critical matter for the commercial trade between two countries, which depend on the energy demand and uranium price. The dynamics simulations show the trend of trade is affected by the several kinds of the aspects. Using system dynamics method, the event quantification is performed for the event flows, stocks, and feedback where the single and double arrow lines are incorporated.

13/01434 DYNSUB: a high fidelity coupled code system for the evaluation of local safety parameters – part II: comparison of different temporal schemes

Gomez-Torres, A. M. *et al. Annals of Nuclear Energy*, 2012, 48, 123–129.

DYNSUB is a novel two-way pin-based coupling of the simplified transport (*SP*₃) version of DYN3D with the subchannel code SUBCHANFLOW. The new coupled code system allows for a more

realistic description of the core behaviour under steady state and transients conditions, and has been widely described in Part I of this paper. Additionally to the explicit coupling developed and described in Part I, a nested loop iteration or fixed point iteration (FPI) is implemented in DYNSUB. A FPI is not an implicit scheme but approximates it by adding an iteration loop to the current explicit scheme. The advantage of the method is that it allows the use of larger time steps; however the nested loop iteration could take much more time in getting a converged solution that could be less efficient than the explicit scheme with small time steps. A comparison of the two temporal schemes is performed. The results using FPI are very promising and represent a very good option in order to optimize computational times without losing accuracy. However it is also shown that a FPI scheme can produce inaccurate results if the time step is not chosen in agreement with the analysed transient.

13/01435 Economic and environmental analysis of power generation expansion in Japan considering Fukushima nuclear accident using a multi-objective optimization model

Zhang, Q. *et al. Energy*, 2012, 44, (1), 986–995.

Nuclear power has long been a cornerstone of energy policy in Japan, a country with few natural resources of its own. However, following on from the Fukushima Daiichi accident, the Japanese government is now in the throes of reviewing its nuclear power policy. On the other hand, under continuing policies of greenhouse gas reduction, it is crucial to consider scenarios for the country to realize an economic, safe and low-carbon power generation system in the future. Therefore, in the present study, economic and environmental analysis was conducted on the power generation system in Japan up to 2030 using a multi-objective optimization methodology. Four nuclear power scenarios were proposed in light of the nuclear accident: (1) actively anti-nuclear; (2) passively negative towards nuclear; (3) conservative towards nuclear; and (4) active expansion of nuclear power. The obtained capacity mix, generation mix, generation cost, CO₂ emissions and fuel consumption of the scenarios were compared and analysed. The obtained results show that the large scale penetration of PV (photovoltaic), wind and liquefied natural gas power can partly replace nuclear power, however, removing nuclear power entirely was not suggested from economic, environmental and energy security perspectives.

13/01436 Heat recovery from nuclear power plants

Safa, H. *International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 553–559.

The thermodynamic efficiency of a standard nuclear power plant (NPP) is around 33%. Therefore, about two-thirds of the heat generated by the nuclear fuel is wasted to the environment. Given the fact that the steam coming out from the high-pressure turbine is superheated, it could be advantageously used for non-electrical applications, particularly for district heating. Considering the technological improvements achieved these last years in heat piping insulation, it is now perfectly feasible to envisage heat transport over quite long distances, exceeding 200 km, with affordable losses. Therefore, it could be energetically wise to revise the modifications required on present reactors to perform heat extraction without impeding NPP operation. In this paper, the case of a French reactor is studied showing that a large fraction of the wasted nuclear heat can be recovered and transported to be injected in the heat distribution network of a large city. Some technical and economic aspects of nuclear district heating application are also discussed.

13/01437 Japan's energy security predicament post-Fukushima

Vivoda, V. *Energy Policy*, 2012, 46, 135–143.

If energy security is defined as the availability of energy at all times in various forms, in sufficient quantities and at affordable prices, without unacceptable or irreversible impact on the economy and the environment, Japan is facing an energy security predicament. For a country that was already uneasy about energy security, the 11 March 2011 earthquake and tsunami, which caused a nuclear catastrophe in TEPCO's Fukushima Daiichi nuclear power plant, turned this unease into outright anxiety. With the temporary and/or permanent closure of many nuclear reactors Japan has had to replace lost power. Tokyo has had no choice but to secure additional fossil fuels, a strategy that has negatively affected Japan's economy due to rising fuel costs. The increase in Japan's fossil fuel consumption has also caused a significant increase in greenhouse gas emissions, and affected Tokyo's commitment to Kyoto targets. This paper analyses the consequences of the 2011 nuclear disaster for Japan's energy security. Recognizing that Japan's future energy policy choices are constrained and path dependent, the paper outlines energy policy recommendations for Japan's government.

13/01438 Radioactive material defense construction using wind fan system against nuclear fallout in the aspect of nano-scopic dispersionWoo, T. H. *Annals of Nuclear Energy*, 2012, 48, 102–107.

A radioactive fallout defence system (RFDS) is suggested against possible nuclear accidents. A procedure consisting of several stages is considered. In particular, the dispersion of radioactive material is investigated for the case of wind fan operation where the radioactive molecules are considered as nanoscopic material. The modelling is done for one country dealing with a possible nuclear accident in another country. This study is thus applicable to regions where westerlies are prevailing. An aerodynamic fan analysis is performed. The incoming free wind stream is characterized by random sampling in Monte Carlo simulation. The velocity of the fan is a critical aspect of the model. This model is applicable for volcanic ashes, nuclear bomb fallout, chemical material dispersion, and any other material combined with airflow. In addition, this fan could be studied, with nanoscale considerations, by a multi-scale technique.

13/01439 The effect of the Fukushima nuclear accident on stock prices of electric power utilities in JapanKawashima, S. and Takeda, F. *Energy Economics*, 2012, 34, (6), 2029–2038.

The purpose of this study is to investigate the effect of the accident at the Fukushima Daiichi nuclear power station, which is owned by Tokyo Electric Power Co. (TEPCO), on the stock prices of the other electric power utilities in Japan. Because the other utilities were not directly damaged by the Fukushima nuclear accident, their stock price responses should reflect the change in investor perceptions on risk and return associated with nuclear power generation. The first finding is that the stock prices of utilities that own nuclear power plants declined more sharply after the accident than did the stock prices of other electric power utilities. In contrast, investors did not seem to care about the risk that may arise from the use of the same type of nuclear power reactors as those at the Fukushima Daiichi station. An increase of both systematic and total risks was also observed in the post-Fukushima period, indicating that negative market reactions are not merely caused by one-time losses but by structural changes in society and regulation that could increase the costs of operating a nuclear power plant.

13/01440 Too hot to touch: the problem of high-level nuclear wasteAlley, W. M. and Alley, R. *Nuclear Waste*, 2013, Cambridge University Press, 383pp.

As nuclear waste sites are debated in the UK and other places, this book documents the US experience of dealing with radioactive waste over the past 60 years.

13/01441 What will the Fukushima disaster change?Thomas, S. *Energy Policy*, 2012, 45, 12–17.

Intuitively, the Fukushima disaster should have a major impact on the future of the nuclear industry. This paper argues that there are four possible answers to the question ‘what will Fukushima change?’: everything because the nuclear industry cannot survive another Chernobyl; the impact will vary according to location; it is too early to determine the impact; and the nuclear industry was facing serious problems that Fukushima will do no more than exacerbate. The authors focus on the last answer, arguing that the new designs that were expected to be so attractive as to power a ‘nuclear renaissance’ were already failing. The promises that they would be safer, but simpler, therefore cheaper and more buildable were unachievable and the renaissance in the West had already failed. If the nuclear industry is to have a future, it might be through a shift in locus from North America and Western Europe to China, Russia and India. However, it is not clear that these countries can avoid the techno-economic issues that have derailed the nuclear industry in the West. The prospect that the nuclear industry can be saved by a radical new generation of designs is a long way off and still a remote possibility.

13/01442 Wind power or uranium mine: appraisal of two energy-related environmental changes in a local contextPedersen, E. and Johansson, M. *Energy Policy*, 2012, 44, 312–319.

This study explores factors associated with the individual's appraisal of anticipated environmental changes caused by energy production facilities. The study took place in a Swedish village where exploratory drilling, that could eventually lead to a uranium mine, was being conducted at the same time as a wind farm was approved. Results from the survey, which included the total population, were interpreted in the light of cognitive stress theory. Most residents thought that the wind farm would have a positive impact on the village but that the uranium drilling would have a negative impact; these opinions were closely related to attitudes towards wind and nuclear power. Perceiving the wind farm as positive was further predicted by young age, high education, being an ordinary rather than a committed recycler and

having attended a meeting about the wind farm. A negative view of uranium drilling was predicted by the individual valuing closeness to nature, being a recycler, and having attended the uranium meeting. Psychological factors such as concerns for the environment (manifested as pro-environmental behaviour), valuing closeness to nature, and involvement impinge on the appraisal process and should be considered when new developments are presented.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

13/01443 A comprehensive circuit model for partial discharge activities in cable insulation due to electrical treeingPour, A. N. and Shahrtash, S. M. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 646–655.

A new comprehensive circuit model is proposed for electrical trees in cable insulation to be used in partial discharge (PD) analyses. Simple relations are presented for each of circuit components. The effect of tree's constructional parameters (such as length, growth angle and type), cable and insulation dimension (such as conductor radius and insulation thickness), needle dimension, temperature and insulation aging are considered in the proposed model. The patterns (pulse sequences, $\varphi-q-n$ and $\varphi-n$) extracted from the proposed model are in a good agreement with the published experimental patterns under different conditions. Moreover, the model is fully compatible with the software packages, such as EMTP, that can simulate pulse propagation along cable networks.

13/01444 A knowledge representation model for the optimisation of electricity generation mixesTahir, A. C. and Bañares-Alcántara, R. *Applied Energy*, 2012, 97, 77–83.

Energy models such as MARKAL, MESSAGE and DNE-21 are optimization tools which aid in the formulation of energy policies. The strength of these models lie in their solid theoretical foundations built on rigorous mathematical equations designed to process numerical (quantitative) data related to economics and the environment. Nevertheless, a complete consideration of energy policy issues also requires the consideration of the political and social aspects of energy. These political and social issues are often associated with non-numerical (qualitative) information. To enable the evaluation of these aspects in a computer model, the authors hypothesize that a different approach to energy model optimization design is required. A prototype energy model that is based on a semantic representation using ontologies and is integrated to engineering models implemented in Java has been developed. The model provides both quantitative and qualitative evaluation capabilities through the use of logical inference. The semantic representation of energy policy goals is used (i) to translate a set of energy policy goals into a set of logic queries which is then used to determine the preferred electricity generation mix and (ii) to assist in the formulation of a set of equations which is then solved in order to obtain a proposed electricity generation mix. Scenario case studies have been developed and tested on the prototype energy model to determine its capabilities. Knowledge queries were made on the semantic representation to determine an electricity generation mix which fulfilled a set of energy policy goals (e.g. CO₂ emissions reduction, water conservation, energy supply security). An optimized electricity generation mix, based on the queried results, was then generated using a custom developed linear programming optimization module.

13/01445 A solar-powered traveling-wave thermoacoustic electricity generatorWu, Z. *et al. Solar Energy*, 2012, 86, (9), 2376–2382.

Travelling-wave thermoacoustic electricity generator is a new external-combustion type device capable of converting heat such as solar energy into electric power. In this paper, a 1 kW solar-powered travelling-wave thermoacoustic electricity generation system is designed and fabricated. The system consists of a travelling-wave thermoacoustic electricity generator, a solar dish collector and a heat receiver. In the preliminary tests, using electric cartridge heaters to simulate the solar

energy, a maximum electric power of 481 W and a maximum thermal-to-electric efficiency of 15.0% were achieved with 3.5 MPa pressurized helium and 74 Hz working frequency. Then, after integrating the travelling-wave thermoacoustic electricity generator with the solar dish collector and the heat receiver, the solar-powered experiments were performed. In the experiments, a maximum electric power of about 200 W was obtained. However, due to the solar dish collector problems, the heating temperature of the receiver was much lower than expected. Optimizations of the collector and the heat receiver are under way.

13/01446 Advances and trends of energy storage technology in microgrid

Tan, X. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 179–191.

Microgrid (MG) is the indispensable infrastructure of today's smart grid, however, fluctuation and intermittence resulted from unstable micro-sources and non-linear loads will execute considerable impacts on normal operation of the MG. Energy storage technology presents a preferable solution to the above issue. The paper gives a review of the principal energy storage technologies being developed so far, and the features and benefits of energy storage systems (ESSs) within the MG are analysed in details including ESS configuration and topologies, power electronics interfaces, ESS control schemes for charging/discharging, control strategy of hybrid ESS as well as optimization of the renewable sources and ESS. The future trends and challenges of ESS are also fully accounted, with a view to proposing smart ESS as the promising technology in the future for MGs and smart grids.

13/01447 Application of multi-stage converter in distributed generation systems

Banaei, M. R. and Salary, E. *Energy Conversion and Management*, 2012, 62, 76–83.

The distributed generation systems are usually connected to the grid through power electronic converters that influence the efficiency of the system. This paper presents a multi-stage converter for distributed generation systems with a new bidirectional converter in output stage that can be a suitable solution for the medium to high-power applications. In addition, a DC/AC converter composed by a high-frequency link bidirectional power converter produces desired output voltage with fewer bidirectional switches and stages. The operation and performance of the suggested converter has been verified by the simulation results using SIMULINK/MATLAB.

13/01448 Carbon based nanotubes and nanopowder as impregnated electrode structures for enhanced power generation: evaluation with real field wastewater

Mohanakrishna, G. *et al. Applied Energy*, 2012, 95, 31–37.

Carbon-based multiwalled nanotubes (MWCNT) and nanopowder (CNP) impregnated using conductive epoxy resin on anodic surface were evaluated for bioelectricity generation in single chambered microbial fuel cells in comparison with plain graphite anode (MFC_P). The study demonstrated the positive function of carbon nanostructures impregnated anode with respect to power generation. MFC_{MWCNT} exhibited higher electrogenic activity (267.77 mW/m²) followed by MFC_{CNP} (168.45 mW/m²) and MFC_P (107.51 mW/m²). MFC_{MWCNT} and MFC_{CNP} showed 148% and 57% enhancement in the power generation, respectively, compared to MFC_P. Microbial mediators were also found to be more effective with modified anodes operation. Impregnation with nanomaterial facilitates higher surface area that enables higher charge transfer from anolyte to electrodes. Impregnated anodes showed marginal influence on substrate degradation. Further, feasibility of MWCNT impregnated anode was evaluated with real field distillery wastewater which depicted good electrogenic activity (245.34 mW/m²) and yield (3.43 W/m³).

13/01449 Design of regional and sustainable bio-based networks for electricity generation using a multi-objective MILP approach

Pérez-Fortes, M. *et al. Energy*, 2012, 44, (1), 79–95.

Biomass energy systems can be employed to meet the requirements of distributed energy systems in rural as well as urban contexts, whether this is an electrification or a microgeneration project. This work is focused on a mathematical programming approach applied to bio-based supply chains that use locally available biomass at or near the point of use in order to produce electricity or other bioproduct. The problem of designing and planning a regional biomass supply chain is formulated as a MO-MILP (multi-objective mixed integer linear program), which takes into account three main objectives: economic, environmental and social criteria. The model supports decision-making about location and capacity of technologies, connectivity between the supply entities, biomass storage periods, matter transportation and biomass utilization. The advantages of this approach are highlighted by solving a case study of a specific district in Ghana. The aim is to

determine the most suitable biomass and electricity network among the different communities. The technology considered to transform the biomass into electricity is gasification combined with a gas engine.

13/01450 Development of a novel method for optimal use of a newly designed reactive power control relay

Sekkeli, M. and Tarkan, N. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 736–742.

In this study, a new method for a reactive power control relay is developed. The method reduces the switching number of contactors, resulting in less active energy losses in the system operated by the reactive power control. The method consists of three main parts. The first part minimizes the delay time that is required to discharge capacitors. The second part develops a new algorithm in order to optimally select the capacitor value, which compensates the measured reactive power value of the system. The third part uses the Goertzel algorithm instead of fast Fourier transformation (FFT) in order to perform harmonic analysis and power calculations of the voltage and current samples obtained from the system. The use of the Goertzel algorithm results in less trigonometric equations and faster calculation time. An electronic circuit that implements the above algorithm is also developed. Theoretical calculations and experimental results are presented.

13/01451 Disaggregating categories of electrical energy end-use from whole-house hourly data

Birt, B. J. *et al. Energy and Buildings*, 2012, 50, 93–102.

The residential sector uses nearly 30% of all electricity in Canada, and it is important to know how this energy is being used, so that savings may be identified and realized. A method is proposed that can be applied to hourly whole-house electrical energy data to partially disaggregate total household electricity use into five load categories/parameters (base load, activity load, heating season gradient, cooling season gradient and lowest external temperature at which air-conditioning is used). This paper develops the proposed method, and verifies it using high-resolution end-use data from 12 households with known characteristics. The authors then apply the method to hourly whole-house (smart meter) data from 327 households in Ontario. The roll-out of smart (advanced) metering infrastructure in many countries will make hourly whole-house data abundant, and it is proposed that this method could be widely applied by utilities to target their demand-side management programs towards households more likely to provide benefits, thus increasing the cost-effectiveness of such programs.

13/01452 Energy and exergy analysis of a fuel cell based micro combined heat and power cogeneration system

Xie, D. *et al. Energy and Buildings*, 2012, 50, 266–272.

A fuel cell-based micro-combined heat and power (CHP) cogeneration system is a cost-effective means of meeting residential energy needs if capital cost targets can be met. The cogeneration system mainly consists of a fuel processing unit, a power generation unit and an auxiliary unit. The fuel-processing unit under investigation includes an autothermal reformer, high and low temperature shift reactors and a CO preferential oxidation reactor. Energy and exergy analysis of the system is useful to investigate the effects of key operating parameters on the system performance. A micro-CHP system that produces approximately 1 kW of electricity is simulated with Aspen Plus. A typical case is analysed and system energy and exergy loss break-down is studied. It is found that for the typical case, energy carried by unuseful streams accounts for the majority of the energy and exergy losses. Among all the components, proton exchange membrane fuel cells possess the least energy efficiency and exergy efficiency. Effects of steam to carbon ratio, air to carbon ratio, hydrogen utilization efficiency, power generation efficiency, and process methane feed variation on system performances are parametrically studied.

13/01453 Exergetic and environmental analysis of a pulverized coal power plant

Restrepo, Á. *et al. Energy*, 2012, 45, (1), 195–202.

This paper presents the results of exergetic and environmental analysis of a typical pulverized coal power plant located in Brazil. The goal was to quantify both the exergy destruction and the environmental impact associated with a thermal power plant. The problem boundary consists of the entire coal delivery route, including mining and beneficiation, transport, pre-burning processes and the power plant. The used data were obtained mainly from field measurements taken in all system processes, from mining to the power plant. The study focused only on the operation period. Previous works have shown that the construction and decommissioning periods contribute less than 1% of the environmental impact. The exergetic analysis was based on the second law of thermodynamics while the environmental analysis was based on life cycle assessment (LCA) using SimaPro 7.2, focusing on the climate change and acidification impact categories. The CO₂-eq emission was 1300 kg per MWh. The highest degree of environmental impact occurred during the combustion process. The exergetic and environ-

mental analysis provides a tool to evaluate irreversibilities and the environmental impact, identifying the most significant stages and equipment of the entire power generation process.

13/01454 Generation risk assessment in volatile conditions with wind, hydro, and natural gas units

Sahin, C. *et al. Applied Energy*, 2012, 96, 4–11.

This paper studies a generating company's (GENCO) midterm (a few months to a year) scheduling payoffs and risks in volatile operating conditions. The proposed algorithm considers the integration of intermittent wind units into a GENCO's generation assets and coordinates the GENCO's hourly wind generation schedule with that of natural gas (NG) units (with volatile gas prices) and hydro units (with water inflow forecast) for maximizing the GENCO's payoff. The proposed midterm GENCO model applies market price forecasts to the risk-constrained stochastic price-based unit commitment (PBUC) for calculating the GENCO's risk in energy and ancillary services markets. The proposed PBUC minimizes the cost of (a) NG contracts, storage, startup and shutdown, (b) startup and shutdown of cascaded hydro units, and (c) penalty for defaulting on the scheduled power delivery. Simulation results show that the diversification of generating assets including bilateral contracts (BCs) could enhance the GENCO's midterm planning by increasing the expected payoff and decreasing the financial risk.

13/01455 Implementing peak load reduction algorithms for household electrical appliances

Dlamini, N. G. and Cromieres, F. *Energy Policy*, 2012, 44, 280–290.

Considering household appliance automation for reduction of household peak power demand, this study explored aspects of the interaction between household automation technology and human behaviour. Given a programmable household appliance switching system, and user-reported appliance use times, the authors simulated the load reduction effectiveness of three types of algorithms, which were applied at both the single household level and across all 30 households. All three algorithms effected significant load reductions, while the least-to-highest potential user inconvenience ranking was: coordinating the timing of frequent intermittent loads (algorithm 2); moving period-of-day time-flexible loads to off-peak times (algorithm 1); and applying short-term time delays to avoid high peaks (algorithm 3) (least accommodating). Peak reduction was facilitated by load interruptibility, time of use flexibility and the willingness of users to forgo impulsive appliance use. The authors conclude that a general factor determining the ability to shift the load due to a particular appliance is the time-buffering between the service delivered and the power demand of an appliance. Time-buffering can be 'technologically inherent', due to human habits, or realized by managing user expectations. There are implications for the design of appliances and home automation systems.

13/01456 Including fuel price elasticity of demand in net present value and payback time calculations of thermal retrofits: case study of German dwellings

Galvin, R. and Sunikka-Blank, M. *Energy and Buildings*, 2012, 50, 219–228.

In the domestic heating sector a number of different mathematical models are used to evaluate the economic viability of thermal retrofit measures. Currently, however, none of these models incorporate the effect of fuel price elasticity of demand. This paper offers a method for incorporating a factor for fuel price elasticity into models for assessing the net present value and payback time of thermal retrofits of existing homes. A set of working equations is developed, and empirically tested in a case study, a housing estate retrofit project in Ludwigshafen, Germany. The value used in these equations for year-on-year price elasticity, -0.476 , is derived from further empirical studies. The inclusion of price elasticity is found to lower the net present value by 14–24% and lengthen the payback time by 5 years in some cases, and hundreds of years in others. It also shows CO₂ saved over the technical lifetime of the retrofit measures to be 15–24% lower than anticipated. These findings have implications for government policy and investment decisions of businesses, private households and housing providers.

13/01457 Integrated management of cogeneration plants and district heating networks

Prato, A. P. *et al. Applied Energy*, 2012, 97, 590–600.

Combined heat and power based district heating networks (CHP/DHN) systems represent nowadays one of the most efficient technologies, as an alternative to standard space heating solutions, leading to lower greenhouse gas emissions in the atmosphere. Dynamic modelling of district heating networks is of considerable importance in order to investigate suitable control strategies aimed to optimize the heat production and to manage the system transients following changes in the required heat. Through the analogous electrical systems modelling approach, a component software library has been developed for icon-based dynamic simulation of district heating networks,

implementing the mathematical models in Matlab/Simulink environment. The calculation procedure that translates into practice the approach described above, complies with a main flow chart designed to allow for the simulation of the system operation in a quicker-than-real time, throughout the controlled time interval, while imposing the assumed duty and site conditions. The procedure's main body, as well as being utilized to assess the feasibility and to carry out the conceptual design, once the plant has started up, can be employed as a guide to the operator. Research activity has been focused on the development and integration of a code for dynamic simulation of heat distribution networks with a code for thermo-economics optimization of CHP systems, increasing the possibility of optimizing the matching between CHP plant and thermal users, through the exploitation of thermal storage capacity of the networks. A CHP-based district heating project in northern Italy was considered as a test case. Results show that integrated management of cogeneration plants and district heating networks allows for the achievement of significant advantages both in terms of economic competitiveness and energy saving; in particular it has been highlighted that only through the support of an intelligent management system it is possible to maximize the potential benefits offered by the exploitation of district heating networks dynamic heat storage capacity.

13/01458 Long term distribution network planning considering urbanity uncertainties

Salehi, J. and Haghifam, M.-R. *International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 321–333.

This paper addresses the problem of long-term distribution network planning under urbanity uncertainties. Unpredictable urbanity plans are expected facts in developing/underdeveloped countries. This type of uncertainties make it difficult to implement designed network in the future and leads to increasing operational costs including loss and outage costs. This paper presents a novel approach for distribution network planning which in addition of eliminating harmful effects of urbanity uncertainties, leads to easy management and operation of resulted network. In this approach several points of study region with high accessibility are selected as candidate embranchment points and optimal connection configuration of load points to the embranchment points is determined by genetic algorithm considering investment, loss and also customer interruption costs. Afterward, final structure of network is designed by branch exchange method considering the embranchment points as representative to load points in their service area. The performance of the proposed approach is assessed on a test distribution network.

13/01459 Online impedance spectroscopy of lead acid batteries for storage management of a standalone power plant

Depernet, D. *et al. Journal of Power Sources*, 2012, 219, 65–74.

This paper presents a contribution to implementation of hybrid power plants in rural areas without electricity in Senegal. Wind and photovoltaic generators coupling is used to benefit from renewable energy resources in this country. Lead-acid storage batteries are coupled with the generators to ensure smoothness of the electricity generation. This work is focused in particular on the development of a low-cost online impedance spectroscopy method to address the problem of limited lifetime of batteries and the difficulties of their maintenance in isolated areas. Control of static converter associated with the battery is adapted to integrate the functionality of characterization of batteries by impedance spectroscopy. An experimental platform developed in the laboratory has validated the method for online measurement of battery impedance spectrum and to initiate a phase of data monitoring.

13/01460 Performance tests of two small trigeneration pilot plants

Rocha, M. S. *et al. Applied Thermal Engineering*, 2012, 41, 84–91.

Trigeneration systems have been used with advantage in the last years in distributed electricity generation systems as a function of a growth of natural gas pipeline network distribution system, tax incentives, and energy regulation policies. Typically, a trigeneration system is used to produce electrical power simultaneously with supplying heating and cooling load by recovering the combustion products thermal power content that otherwise would be driven to atmosphere. Concerning that, two small-scale trigeneration plants have been tested for overall efficiency evaluation and operational comparison. The first system is based on a 30 kW (ISO) natural gas powered microturbine, and the second one uses a 26 kW natural gas powered internal combustion engine coupled to an electrical generator as a prime mover. The stack gases from both machines were directed to a 17.6 kW ammonia–water absorption refrigeration chiller for producing chilled water first and next to a water heat recovery boiler in order to produce hot water. Experimental results are presented along with relevant system operational parameters for appropriate operation including natural gas consumption, net electrical and thermal power production, i.e. hot

and cold water production rates, primary energy saving index, and the energy utilization factor over total and partial electrical load operational conditions.

13/01461 Probabilistic modeling of a parabolic trough collector power plant – an uncertainty and sensitivity analysis

Zaversky, F. *et al. Solar Energy*, 2012, 86, (7), 2128–2139.

In this work, an uncertainty and sensitivity analysis for the annual performance of a parabolic trough collector plant based on a probabilistic modelling approach of the solar-to-thermal energy conversion process has been accomplished. Realistic probability functions have been assigned to the most relevant solar field performance parameters. The Latin hypercube sampling method has been used to create equal probable parameter combinations. The obtained sample matrix has been used to run multiple annual electricity yield simulations in SimulCET, a validated parabolic trough collector plant simulation software, developed by the National Renewable Energy Centre in Spain. This procedure has led to a representative distribution for the annual plant performance, given the uncertainty in the input data. For this study the parabolic trough power plant model has been run in solar driven operation mode, without the use of thermal storage or fossil fuel back up. While being aware of the great influence of the solar irradiation on the power plant performance, only one single reference meteorological year has been used as solar input data. This has been done in order to emphasize the influence of technical design as well as solar field maintenance parameters, factors that can be controlled or affected by mankind. In order to assess and rank the impact of each varied model parameter a multiple linear regression has been performed. The standardized regression coefficients, the Pearson correlation coefficients as well as the coefficient of multiple determination R^2 are discussed. Varied parameters are the collector mirror reflectance, the collector mirror cleanliness factor, the collector glass tube transmittance, the collector receiver tube absorptance, and the collector receiver tube heat loss characteristic. Based on existing and published bibliography, a set of parameter distributions and ranges have been chosen for this work and the simulation results show that the cleanliness factor has the strongest influence on the model output. The cleanliness is followed (in this sequence) by the mirror reflectance, the glass tube transmittance, the receiver tube absorptance and, finally, by the receiver tube heat loss characteristic.

13/01462 Steady state electric power generation in up-flow microbial fuel cell using the estimated time span method for bacteria growth domestic wastewater

Hashemi, J. and Samimi, A. *Biomass and Bioenergy*, 2012, 45, 65–76.

The parameters affecting steady state power generation for a lab-scale up-flow microbial fuel cell (UMFC) were studied. Single batch of domestic wastewater substrate was initially fed to the UMFC to determine the time span of maximum anaerobic bacterial activity by monitoring their lag, growth and death phases. This was performed indirectly by recording the variations in volumetric electric power with time. The UMFC was then operated using the batches of substrate, fed sequentially from anaerobic basins when the previously estimated time span showed the maximum activity of bacteria in the basin. At the maximum bacterial activity, the UMFC could continuously generate constant volumetric power of approximately $5.31 \pm 0.12 \text{ W m}^{-3}$. The effects of organic loading rate, flow rate and pH of the domestic wastewater on the voltage and volumetric electric current were also investigated. The results showed that increasing the organic loading rate and flow rate at neutral pH enhanced the voltage. A higher power could be generated using the UMFC for domestic wastewater treatment, as compared to the other works.

13/01463 Study of pumped storage schemes to support high RES penetration in the electric power system of Greece

Anagnostopoulos, J. S. and Papantonis, D. E. *Energy*, 2012, 45, (1), 416–423.

Energy storage constitutes an effective way to manage excess production from renewable energy schemes (RES), and pumped storage is a suitable and mature solution for large storage capacities. The present study aims to investigate the performance of a pumped storage unit introduced in a conventional hydroelectric power plant in Greece. At first, the plant operation and the electric grid data for a reference period of one year are used to compute the time variation of water inflow into the dam, and to estimate the RES production rejections depending on the installed power. Next, a pumping station powered by the rejected RES production and raising water from an adjacent downstream reservoir is modelled. Various scenarios concerning the pumping station power rate and feeding program are examined. The operation of the combined system is simulated in detail and the energy results are analysed. Also, an economic evaluation is carried out based on current financial conditions in Greece. The results showed that a considerable amount of excess RES production can be stored, but the economic viability of the investment depends on some

critical parameters, which are identified. Certain guidelines concerning the optimum sizing and operation strategy of the pumped storage scheme are finally extracted.

13/01464 The frequency-independent control method for distributed generation systems

Naderi, S. *et al. Applied Energy*, 2012, 96, 272–280.

In this paper a novel frequency-independent control method suitable for distributed generation (DG) is presented. This strategy is derived based on the $abc/\alpha\beta$ transformation and abc/dq transformation of the ac system variables. The active and reactive currents injected by the DG are controlled in the synchronously rotating orthogonal dq reference frame. The transformed variables are used in control of the voltage source inverter that connects DG to distribution network. Due to importance of distributed resources in modern power systems, development of new, practical, cost-effective and simple control strategies is obligatory. The new control method of this paper does not need a phase-locked loop in control circuit and has fast dynamic response in providing active and reactive power to non-linear load. From extensive simulation results, high performance of this control strategy in DG application is demonstrated with improved voltage profile, increased power factor and reduced total harmonic distortion.

13/01465 The study of directional overcurrent relay and directional earth-fault protection application for 33 kV underground cable system in Malaysia

Bakar, A. H. A. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 40, (1), 113–119.

Differential protection scheme is based on comparison of measured variables such as current and voltage at the two ends of a line via a communication channel such as pilot wire. This scheme is preferred and extensively used in distribution feeder protection system in Malaysia due to its fast operation. However pilot-wire differential scheme has its own drawbacks especially on the maintenance of the pilot-wire. Once the pilot-wire is out of service, the feeder protection is jeopardized. One of the options to overcome such maintenance issue is to adopt directional relay as the feeder protection. This paper investigates a suitable relay connection and the maximum torque angle for the directional relay for 33 kV underground network. In this study, a section of 33 kV underground network in Kuala Lumpur city has been analysed. All faults types have been simulated at all possible location in the network. The obtained voltage and current were then used to determine the operation of directional overcurrent and earth-fault relay. The simulation results indicate that 30° relay connection with 0° maximum torque angle ($30^\circ/0^\circ$) is the most suitable setting to be applied for 33 kV underground network in Kuala Lumpur, as against the best general and most versatile setting, $45^\circ/90^\circ$.

13/01466 Thermal regenerative design of a fuel cell cogeneration system

Hwang, J.-J. *Journal of Power Sources*, 2012, 219, 317–324.

The objective of the present work is to design and fabricate a thermal management system (TMS) that commands a proton exchange membrane fuel cell (PEMFC) based cogeneration system to generate the electricity and hot water efficiently. Parametric studies include the external load (P_L) and the regenerative temperature (T_R). A thermostat valve is employed to optimize the stack operation temperature, while a thermal regenerative unit (TRU) containing a planar heat exchanger is used to recover the heat dissipated by the stack. First, the dynamics of thermal and electrical characteristics such as voltage, current, power, coolant temperature, coolant flow rate, and hydrogen flow rate are measured to check the reliability of the TMS. Then, the effectiveness of the planar heat exchanger is determined to verify the cooling ability of the TRU. Moreover, the transient system efficiencies, including electrical efficiency, thermal efficiency, and overall efficiency are determined. Furthermore, the effect of the regenerative temperature on the time-averaged system efficiencies is examined under different external loads. Finally, an empirical correlation for time-averaged overall efficiency is proposed for helping in design of the PEMFC cogeneration system.

13/01467 Variable-speed technology used in power plants for better plant economics and grid stability

Wang, W. *et al. Energy*, 2012, 45, (1), 588–594.

The objective of this research is to simultaneously reduce energy requirements along with rapid and broad load ranges using variable-speed pumps (VSPs) in thermal power plants. This paper proposes a novel algorithm to calculate the operating points of VSP. A case study on the operation optimization of condenser cooling water pump shows that VSP is far superior to fixed-speed pump in terms of energy savings. Vacuum adjustment system is established to improve the capability of thermal power plants in executing rapid load changes. The authors also bring forth a proposal to establish an automatic variable-speed control system to ensure safety, economy, and stability of the units and grid operations.

Economics, policy, supplies, forecasts

13/01468 A hybrid intelligent approach for the prediction of electricity consumption

Amina, M. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 99–108.

Power load forecasting is an essential tool for energy management systems. Accurate load forecasting supports power companies to make unit commitment decisions and schedule maintenance plans appropriately. In addition to minimizing the power generation costs, it is also important for the reliability of energy systems. This research study presents the implementation of a novel fuzzy wavelet neural network model on an hourly basis, and validates its performance on the prediction of electricity consumption of the power system of the Greek island of Crete. In the proposed framework, a multiplication wavelet neural network has replaced the classic linear model, which usually appears in the consequent part of a neurofuzzy scheme, while subtractive clustering with the aid of the expectation–maximization algorithm is being utilized in the definition of fuzzy rules. The results related to the minimum and maximum load using metered data obtained from the power system of the Greek island of Crete indicate that the proposed forecasting model provides significantly better forecasts, compared to conventional neural networks models applied on the same dataset.

13/01469 A method to determine the power to heat ratio, the cogenerated electricity and the primary energy savings of cogeneration systems after the European Directive

Frangopoulos, C. A. *Energy*, 2012, 45, (1), 52–61.

According to the European Union Directive for the promotion of cogeneration, in order for cogeneration systems to be eligible for economic and financial benefits, they must comply with certain requirements regarding efficiency and primary energy savings. Therefore, the calculation of these two performance indicators, together with the electrical and/or mechanical energy produced in connection with the useful heat, is of crucial importance for the economic viability of these systems. In the present work, the main questions that have to be answered on this subject are posed, and a complete procedure to answer the questions and perform the necessary calculations is presented. This work not only is useful for the current needs, but also gives specific hints for future revision of the Directive on cogeneration and the related texts.

13/01470 A multi-objective optimization model for sustainable electricity generation and CO₂ mitigation (EGCM) infrastructure design considering economic profit and financial risk

Han, J.-H. *et al. Applied Energy*, 2012, 95, 186–195.

A large number of research works were undertaken for the planning of sustainable electricity generation and CO₂ mitigation (EGCM) infrastructure design under uncertainty. The typical methodologies assessed the performance of the problem under the variability of the uncertain parameters by optimizing the expected value of the objective function. This approach can have large probabilities of the value optimized in unfavourable scenarios. This paper presents a mathematical programming model to plan sustainable electricity generation and CO₂ mitigation (EGCM) infrastructure design, including financial risk management under uncertainty. The proposed model helps determine the available technologies to produce electricity and treat CO₂ on the purpose of maximizing the expected total profit and minimizing the financial risk of handling uncertain environments (i.e. CO₂ mitigation operating costs, carbon credit prices and electricity prices, etc.), while fulfilling electricity demands and CO₂ mitigation standards. Simulation results have shown that petroleum-fired electricity generation should be replaced by coal-fired power plants to reduce the variability of the profit distribution. The authors propose the optimal operation of each power plant under uncertainty. These characteristics of the model can help policy managers to enhance the knowledge on how to establish optimal EGCM infrastructures capable of dealing with uncertainties in realistic problems. Finally, nuclear power generation plays an important role in electricity generation in Korea. Besides carbon emissions trading (CET) and carbon capture and storage (CCS), replacing existing fossil fuel plants with nuclear plants can provide more valuable insights on making investment strategies for planning optimal EGCM infrastructures. Therefore it would be worthwhile to extend the proposed modelling approach for developing a new objective function including building a new nuclear power plant in terms of addressing another option of CO₂ mitigation method as well as evaluating the effects of CET and CCS in existing fossil fuel plants as a future work.

13/01471 A proposed grey model for short-term electricity price forecasting in competitive power markets

Lei, M. and Feng, Z. *International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 531–538.

In order to improve the performance of traditional grey models for short-term electricity price prediction in competitive power markets, a novel grey model, named PGM(1,2,a,b), is proposed in this paper. In the proposed model, the reference sequence is determined with correlation method. Furthermore, considering the limitation of the least square method (LSM), particle swarm optimization algorithm is adopted to identify the parameters instead of LSM. To demonstrate the superiority of the proposed model, public available data coming from Nordpool, California, and Ontario power markets were used for training and testing. Simulation results show that the proposed model is capable of forecasting short-term electricity price efficiently and accurately.

13/01472 A scenario driven multiobjective primary–secondary distribution system expansion planning algorithm in the presence of wholesale–retail market

Nazar, M. S. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 40, (1), 29–45.

This paper presents a novel approach for integrated generation and primary–secondary distribution system expansion planning (IGDSEP) in the presence of wholesale and retail markets. The proposed method uses a model to explore the impacts of wholesale and retail market on IGDSEP procedure. This algorithm decomposes the IGDSEP problem into six subproblems to achieve an optimal expansion planning of a system, in which the investment and operational costs are minimized, while the reliability of the system is maximized. The proposed model of IGDSEP is a mixed integer non-linear programming (MINLP) problem and a scenario driven MINLP (SCMINLP) method is proposed for solving the problem. The algorithm was successfully tested for an urban distribution system.

13/01473 Application of SVR with chaotic GASA algorithm in cyclic electric load forecasting

Zhang, W. Y. *et al. Energy*, 2012, 45, (1), 850–858.

The electric load forecasting is complicated, and it sometimes reveals cyclic changes due to cyclic economic activities or climate seasonal nature, such as hourly peak in a working day, weekly peak in a business week, and monthly peak in a demand planned year. Hybridization of support vector regression (SVR) with chaotic sequence and evolutionary algorithms has successfully been applied to improve forecasting accuracy, and to effectively avoid trapping in a local optimum. However, it has not been widely explored to employ SVR-based model to deal with cyclic electric load forecasting. This paper will firstly investigate the potentiality of a novel hybrid algorithm, namely chaotic genetic algorithm-simulated annealing algorithm (CGASA), with an SVR model to improve load forecasting accurate performance. In which, the proposed CGASA employs internal randomness of chaotic iterations to overcome premature local optimum. Secondly, the seasonal mechanism will then be applied to well adjust the cyclic load tendency. Finally, a numerical example from an existed reference is employed to compare the forecasting performance of the proposed SSVRCGASA model. The forecasting results show that the SSVRCGASA model yields more accurate forecasting results than ARIMA and TF- ϵ -SVR-SA models.

13/01474 Comparison of UPFC and Sen transformer for ATC enhancement in restructured electricity markets

Kumar, A. and Kumar, J. *International Journal of Electrical Power & Energy Systems*, 2012, 41, (1), 96–104.

Available transfer capability (ATC) is an important indicator of remaining transfer capability in the transmission network for its commercial use in a competitive electricity market. In this paper, comparison of unified power flow controller (UPFC) and Sen transformer (ST) for ATC enhancement has been presented using an optimal power flow based approach. The ZIP load model along with constant power load have also been incorporated in an OPF model to determine ATC and observe the impact of the ZIP load model. Different combinations of coefficients of ZIP load have been considered to find an impact on ATC without and with FACTS devices. Based on the results obtained, it is concluded that ATC increases in the presence of UPFC and ST for all types of transactions and under intact and line contingency cases. The performance of ST is comparable to that of UPFC in ATC enhancement. With ZIP load model incorporation, ATC is found to decrease compared to constant P , Q load model. With change in location of UPFC and ST and ZIP load coefficients combinations, ATC varies with its maximum values found at optimal location. ST being a low-cost device compared to UPFC and can provide economical solutions for power flow control and ATC enhancement with more number of devices in a system deployed at strategic locations.

13/01475 Competition in the European electricity markets – outcomes of a Delphi studyMakkonen, M. *et al. Energy Policy*, 2012, 44, 431–440.

Internal European electricity markets are a target set by the European Union (EU) and under development at present. This article presents the findings of a Delphi study focusing on the prospects of European electricity markets. The main aim is to report the obstacles that participants in the survey felt were the most critical ones affecting competition in the European electricity markets of the future. The respondents were European electricity market specialists, and the themes of the survey ranged from transmission networks and electricity trade to demand flexibility. One of the key findings was shared concern over the adequacy of transmission network capacity in Europe. It was considered that technical issues, such as existing transmission network bottlenecks, are most likely to form obstacles to creating common European electricity markets if new capacity is not built quickly enough. It was seen by the panellists that electricity trading arrangements, while important, are unlikely to form a barrier to the development of an internal electricity market. It was noted that electricity trading issues have recently been the subject of development work in the EU.

13/01476 Compressor washing economic analysis and optimization for power generationAretakis, N. *et al. Applied Energy*, 2012, 95, 77–86.

The deregulation of the energy market has created an additional incentive for gas turbine plant operators to minimize and control performance deterioration with respect to the economic aspects of the plant. The most prevalent deterioration problem is compressor fouling, which has a significant impact on the power plant profit. Off-line washing is able to recover the engine's performance losses due to fouling, but has a variety of associated costs. A method to predict the impact of the compressor washing process on the power plant revenue is presented herein, allowing for the optimization of the process with regards to power plant specific data. For this reason, a detailed cost analysis module is formed and coupled with an engine model allowing for the study of both economic parameters and engine operation parameters like the increase of maintenance cost due to start-ups and the variation of the engine degradation rate. The method is applied for the case of an aeroderivative gas turbine of 42 MW. The parameters associated with the off-line washing process and the engine performance that affects the plant's revenue are examined and discussed, while recommendations on the optimal washing schedule are made.

13/01477 Cyclic electric load forecasting by seasonal SVR with chaotic genetic algorithmHong, W.-C. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 604–614.

Application of support vector regression (SVR) with chaotic sequence and evolutionary algorithms not only could improve forecasting accuracy performance, but also could effectively avoid converging prematurely (i.e. trapping into a local optimum). However, the tendency of electric load sometimes reveals cyclic changes (such as hourly peak in a working day, weekly peak in a business week, and monthly peak in a demand planned year) due to cyclic economic activities or climate seasonal nature. The applications of SVR model to deal with cyclic electric load forecasting have not been widely explored. This investigation presents a SVR-based electric load forecasting model which applied a novel hybrid algorithm, namely chaotic genetic algorithm (CGA), to improve the forecasting performance. With the increase of the complexity and the larger problem scale of tourism demands, genetic algorithm (GA) is often faced with the problems of premature convergence, slowly reaching the global optimal solution or trapping into a local optimum. The proposed CGA based on the chaos optimization algorithm and GA, which employs internal randomness of chaos iterations, is used to overcome premature local optimum in determining three parameters of a SVR model. A numerical example from an existed reference is used to elucidate the forecasting performance of the proposed SSVRCGA model. The forecasting results indicate that the proposed model yields more accurate forecasting results than ARIMA and TF- ϵ -SVR-SA models. Therefore, the SSVRCGA model is a promising alternative for electric load forecasting.

13/01478 Effects of aggregating electric load in the United StatesCorcoran, B. A. *et al. Energy Policy*, 2012, 46, 399–416.

This study quantifies the effects of aggregating electric load over various combinations (aggregation groupings) of the 10 Federal Energy Regulatory Commission (FERC) regions in the contiguous US generator capacity capital cost savings, load energy shift operating cost savings, reserve requirement cost savings, and transmission costs due to aggregation were calculated for each aggregation grouping. Eight scenarios of aggregation groupings over the USA were formed to estimate overall system cost. Transmission costs outweighed cost

savings due to aggregation for all scenarios and nearly all aggregation groupings. East–west transmission layouts had the highest overall cost, and interconnecting ERCOT to adjacent FERC regions resulted in increased costs, both due to limited existing transmission capacity. This study found little economic benefit of aggregating electric load alone (e.g. without aggregating renewable generators simultaneously), except in the west and northwest USA. If aggregation of load alone is desired, small, regional consolidations yield the lowest overall cost. This study neither examines nor precludes benefits of interconnecting geographically dispersed renewable generators with load. It also does not consider effects from sub-hourly load variability, fuel diversity and price uncertainty, energy price differences due to congestion, or uncertainty due to forecasting errors; thus, results are valid only for the assumptions made.

13/01479 Electric power system generation expansion plans considering the impact of smart grid technologiesTekiner-Mogulkoc, H. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 229–239.

This research investigates how the electric power system generation expansion plans change and improve based on the availability of smart grid technologies. The new model specifically considers (i) the availability of smart grid technologies improving the performance of the distribution system, and/or (ii) the availability of the technologies shifting the demand from peak hours to off-peak hours. Multi-objective multi-period generation expansion planning problems are solved to determine the electricity generation technology options to be added, and where in the grid they should be constructed to simultaneously minimize multiple objectives such as cost and air emissions, e.g. CO₂. Unmet demand is also considered as a cost in the objective function so that the proposed approach considers the reliability of the system. The approach used here explicitly considers availability of the system components and operational dispatching decisions. Monte Carlo simulation is used to generate component availability scenarios, and then, the mixed-integer optimization problem is solved to find optimum expansion solutions considering these scenarios.

13/01480 Estimating the marginal cost of quality improvements: the case of the UK electricity distribution companiesJamash, T. *et al. Energy Economics*, 2012, 34, (5), 1498–1506.

This paper develops an econometric approach to the estimation of marginal costs of improving quality of service. Estimating marginal costs of quality can help energy regulators to design more effective incentive mechanisms for network utilities to achieve optimal quality levels and reduce welfare losses due to sub-optimal quality. The methodology was implemented by way of applying it to the case of the UK electricity distribution networks. The proposed method allows the measurement of the welfare effect of the observed quality improvements in the UK between 1995 and 2003. The results suggest that the regulatory incentives to reduce service interruptions have not been strong enough to achieve economically efficient levels of service quality. It was found that the incentives to encourage utilities to reduce network energy losses have led to performance improvement. It was estimated that the observed improvements in quality during the period of the study only represented about 20% of the potential customer welfare gains, hence leaving considerable scope for further economically efficient improvements in service quality.

13/01481 Hybrid coal-fired power plants with CO₂ capture: a technical and economic evaluation based on computational simulationsHuang, Y. *et al. Fuel*, 2012, 101, 244–253.

Pulverized coal-fired (PC) power plants are the major technology used to generate electricity for power generation around the world. These processes are generally considered to make a significant contribution to global climate change since they have high CO₂ emissions, with the exception of those coal-fired power plants that employ CO₂ capture and storage (CCS) technology. With regard to coal-fired power plants, two main options for capturing CO₂ from flue gases can be adopted, namely post-combustion and oxy-fuel combustion systems. The former technology option separates CO₂ from the flue gas generated by the combustion of coal with air. For chemical absorption, generally a solvent such as MEA is used. However, there is a serious concern about the energy consumption required for regeneration of the solvent MEA. Oxy-fuel combustion systems, on the other hand, involve separating the oxygen from air and then burning the coal in a mixture of pure oxygen and recycled flue gas. This approach reduces the amount of flue gas substantially and simplifies the separation process due to the absence of nitrogen and argon in the stream. However there are some drawbacks in connection with some components, such as air separation units (ASU), which require high capital and operating costs and are energy intensive. A new idea proposed elsewhere was a hybrid of oxy-combustion and post-combustion capture and would use air with O₂ enrichment. Such PC power stations would use an ASU plant to obtain

O₂ enrichment and would still require the CO₂ purification and compression processes. The ASU plant would be smaller than for oxy-fuel and the CO₂ purification and compression systems would be smaller than for air-firing. This paper is to evaluate the proposed process technically and economically based on detailed simulation. The hybrid coal-fired power plant with CO₂ capture system has the potential advantage of reducing energy consumption and costs. To explore the advantages and disadvantages of the hybrid process with CO₂ capture, a comparative analysis of the supercritical PC power plant is carried out. The technical design and the mass and energy balances are implemented by using the ECLIPSE simulation package.

13/01482 Impacts of ice storage on electrical energy consumptions in office buildings

Sehar, F. *et al. Energy and Buildings*, 2012, 51, 255–262.
Cooling demand constitutes a large portion of total electrical demand for office buildings during peak hours. Ice storage technology can help shift this peak cooling demand to off-peak periods. This research analyses the chiller energy consumption of conventional non-storage and ice storage cooling systems for large and medium-sized office buildings in diverse climate zones. Demand response quick assessment tool (DRQAT) has been used to model and simulate large and medium-sized office buildings. The construction and weather files in DRQAT have been modified to incorporate construction standard and weather data for the cities representing the diverse climate zones. Results indicate that the chiller energy consumption for non-storage and ice storage systems depends highly on climatic conditions. Climate zones with hot summers as well as small day and night temperature variations show higher chiller energy consumptions. The marine climate zone has the lowest chiller energy consumption. The cold/humid climate zone has higher chiller energy consumption than the cold/dry and very cold climate zones. The cold/dry and very cold climate zones have comparable chiller energy consumption. Research findings as presented in this paper will help utilities and building owners to quantify the benefits of installing ice storage systems in office buildings located in different climatic conditions.

13/01483 Large-scale urban renewable electricity schemes – integration and interfacing aspects

Lund, P. *Energy Conversion and Management*, 2012, 63, 162–172.
Large-scale renewable electricity schemes (RES) for urban areas are investigated here with emphasis on RES integration and interfacing with the energy system to limit the outflow of RES electricity outside the city boundaries. Different electricity-to-thermal energy strategies to supply heating and cooling demands were also investigated to enable higher than usual RES shares through converting surplus renewable electricity into thermal energy which often constitute a major part of the end-use energy in a city. Case examples from a southern climate (Shanghai, China) with distributed PV schemes and a northern city (Helsinki, Finland) with off-shore seaside wind power were analysed. The results from the Shanghai case indicate that when using thermal storage options, doubling of the photovoltaic capacity from the self-use limit of PV could be possible. With optimal electricity-to-thermal energy strategies and energy management, a 40–65% solar fraction of yearly electricity could be possible. In the Helsinki climate with wind power coinciding with the seasonal load peak, RES may satisfy beyond 30% of all energy and beyond 70% of all electricity demand annually. The size of thermal storage needed in the above cases is between 10 and 100 GWh. A higher RES use leads to higher spatial power flows and power variability in the city which requires more sophisticated control strategies and flexible auxiliary power options to handle transmission bottlenecks.

13/01484 Liquidity and dirty hedging in the Nordic electricity market

Frestad, D. *Energy Economics*, 2012, 34, (5), 1341–1355.
Hedging involves tradeoffs in incomplete markets because the number of hedging instruments is limited. Even when an extensive set of hedging instruments is available, the ease with which these instruments can be traded may be highly variable. This study finds systematic variations in liquidity in different segments of the Nordic electricity swap market and analyses the potential for replacing low-liquidity, delivery-period-matched hedging instruments with more liquid, delivery-period-mismatched hedging instruments. When the costs of implementing such dirty hedging strategies are lower than those of the replaced hedging instruments and the loss of hedge effectiveness is small, dirty hedging strategies may then replace their delivery-period-matched counterparts. In this context, the author analyses the dynamic out-of-sample tracking performance of selected dirty hedges. Electricity swaps with delivery in front year one and two, respectively, track electricity swaps with delivery in front year three quite well. This suggests that hedge effectiveness can be traded off for the reduced costs of implementing these dirty hedging strategies compared with those of the less liquid year-three swaps.

13/01485 Managing the financial risks of electricity producers using options

Pineda, S. and Conejo, A. J. *Energy Economics*, 2012, 34, (6), 2216–2227.

Electricity producers participating in electricity markets face risks pertaining to both selling prices and the availability of the production units. Among electricity derivatives, options represent an adequate instrument to manage these risks. This paper proposes a multi-stage stochastic model to determine the optimal selling strategy of a risk-averse electricity producer including options, forward contracts, and pool trading. A detailed case study highlights the advantages of an option vs a forward contract to hedge against the financial risks related to pool prices and unexpected unit failures.

13/01486 Market-based valuation of transmission network expansion. A heuristic application in GB

Chamorro, J. M. *et al. Energy*, 2012, 44, (1), 302–320.

Transmission investments are currently needed to meet an increasing electricity demand while enhancing security of supply, promoting competition, and integrating renewable energy. A key issue when assessing the benefits from an expanded grid concerns the valuation of the uncertain cash flows that result from the expansion. The authors develop a valuation model which combines optimization techniques, Monte Carlo simulation over the expansion project lifetime, and market data from futures contracts on commodities. This multivariate stochastic model accounts for uncertain dynamics on both the demand side and the supply side. It can assist decision makers when confronted with challenging strategic portfolio choices regarding generation and transmission infrastructures. Although the ultimate goal is to develop a generalizable model, to demonstrate the model by example the authors consider a simplified network with two nodes. They then focus on the proposed western HVDC subsea link between England/Wales and Scotland, and simulate the whole distribution of effects on major system variables over its useful life.

13/01487 Methodology for generating electric load profiles for sizing an electric energy generation system

Orlando, A. F. *et al. Energy and Buildings*, 2012, 52, 161–167.

Electric energy prices in Brazil are higher during 3 h of peak consumption on working days; however, consumers could use a generator system for partially reducing the electricity costs from utility company during peak hours. The process of sizing a generator system begins developing the so-called load capacity curve, using acquired building electricity consumption data. The local utility company supplies this data only for the last month of operation; consequently, data are unavailable for the rest of the year. In order to overcome the difficulty, this paper develops two methodologies to estimate the curve for every month of the year. The first one uses the frequency of occurrence of the measured values of the load power in each bin and the last one the monthly values of load power and energy consumption, as supplied by the local utility monthly bills. In order to validate the methodologies, monthly utility bills and consumption data of electric energy measured at Pontifical Catholic University of Rio de Janeiro, every 15 min over a 4-year period, have been used. Finally a generator system was sized, minimizing the electrical energy cost supplied by it, when the generator meets partially the building load.

13/01488 Modeling and analysis of a decentralized electricity market: an integrated simulation/optimization approach

Sarica, K. *et al. Energy*, 2012, 44, (1), 830–852.

In this study, a model is developed to investigate the implications of an hourly day-ahead competitive power market on generator profits, electricity prices, availability and supply security. An integrated simulation/optimization approach is employed integrating a multi-agent simulation model with two alternative optimization models. The simulation model represents interactions between power generator, system operator, power user and power transmitter agents while the network flow optimization model oversees and optimizes the electricity flows, dispatches generators based on two alternative approaches used in the modelling of the underlying transmission network: a linear minimum cost network flow model and a non-linear alternating current optimal power flow model. Supply, demand, transmission, capacity and other technological constraints are thereby enforced. The transmission network, on which the scenario analyses are carried out, includes 30 bus, 41 lines, nine generators and 21 power users. The scenarios examined in the analysis cover various settings of transmission line capacities/fees, and hourly learning algorithms. Results provide insight into key behavioural and structural aspects of a decentralized electricity market under network constraints and reveal the importance of using an AC network instead of a simplified linear network flow approach.

13/01489 Multi-agent based experimental analysis on bidding mechanism in electricity auction markets

Liu, Z. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 696–702.

Determining the best market pricing rule is a controversial issue in the design of electricity auction markets. Pay-as-bid (PAB) has been proposed to replace the market-clearing price (MCP) in deregulated electricity markets, with the expectation that it would lower market prices and reduce price volatility. A multi-agent based experiment was constructed to compare and analyse the balanced process of the two auction mechanisms. Each adaptive agent represents a generator who develops a bid price and quantity based on a reinforcement learning algorithm. In the simulation experiments, the experimental results are not as expected. Before the market reaches equilibrium, the market price with the PAB mechanism is lower than it is with the MCP mechanism. However, the market price in the PAB mechanism is higher than it is with the MCP when the market achieves a state of equilibrium. With the PAB mechanism, the volatility of volume and price of each generator is less than it is with the MCP system, as expected. The experimental results also show that unconscious collusion behaviours by generators during the game process are a key reason for producing generator market power in the two auction mechanisms.

13/01490 Optimal operation of a 1-kW PEMFC-based CHP system for residential applications

Oh, S.-D. *et al. Applied Energy*, 2012, 95, 93–101.

Fuel-cell-based cogeneration systems are very attractive because of their high electrical efficiency and low emissions of air pollutants. The polymer electrode membrane fuel cell (PEMFC) is especially appropriate for distributed power generation applications because it can be operated at relatively low temperatures and the system is less sensitive to the CO₂ produced during the fuel reforming process. In this study, the optimal operating condition were determined for a 1-kW PEMFC-based combined heat and power (CHP) system based on the daily electricity and heat demand patterns for an apartment house in Korea, whose average monthly electricity and heat demands are 472 and 1312 kWh, respectively. In addition, the unit cost of electricity was estimated using a thermoeconomic analysis and the economic gain achieved by introducing the PEMFC-based CHP system in the apartment house was calculated. Approximately 20% savings can be achieved in the operational cost of the PEMFC-based CHP system, if the installation cost is supported by the government.

13/01491 Pattern analysis and classification for security evaluation in power networks

Kalyani, S. and Swarup, K. S. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 547–560.

Security evaluation is a major concern in real time operation of electric power networks, exhibiting behavioural patterns under abnormal conditions. Security assessment and evaluation can be viewed as a pattern analysis task identifying abnormal patterns of the power system behaviour under highly loaded conditions. Traditional method of security evaluation are highly time consuming and infeasible for direct on-line implementation. This paper presents application of pattern directed inference system for static and transient security evaluation and classification. A straightforward and quick procedure called the sequential forward selection method is used for feature selection process. The classifier model in the pattern directed inference system is designed using different pattern classifier algorithms, namely, conventional, neural network and machine learning classifiers. Support vector machine (SVM), one of the popular machine learning classifiers, is recognized as a suitable pattern classifier for security evaluation problem. The generalization performance of SVM classifier is greatly influenced by the proper setting of its parameters. This paper also addresses different heuristic optimization techniques used in the selection of SVM parameters. The design, development and performance of different classifiers for power system security classification are presented in detail. Simulation work is performed on standard New England 39-bus benchmark system and the feasibility of implementation of the proposed SVM based classifier system for on-line security evaluation is also discussed.

13/01492 Price-based demand side management: assessing the impacts of time-of-use tariffs on residential electricity demand and peak shifting in northern Italy

Torriti, J. *Energy*, 2012, 44, (1), 576–583.

One of the most common demand side management programs consists of time-of-use (TOU) tariffs, where consumers are charged differently depending on the time of the day when they make use of energy services. This paper assesses the impacts of TOU tariffs on a dataset of residential users from the Province of Trento in northern Italy in terms of changes in electricity demand, price savings, peak load shifting and peak electricity demand at sub-station level. Findings highlight that TOU tariffs bring about higher average electricity consumption and

lower payments by consumers. A significant level of load shifting takes place for morning peaks. However, issues with evening peaks are not resolved. Finally, TOU tariffs lead to increases in electricity demand for substations at peak time.

13/01493 Pricing electricity from residential photovoltaic systems: a comparison of feed-in tariffs, net metering, and net purchase and sale

Yamamoto, Y. *Solar Energy*, 2012, 86, (9), 2678–2685.

Three mechanisms are commonly employed to enable households to sell electricity from grid-connected residential solar photovoltaic (PV) systems to utilities or grid companies: feed-in tariffs (FIT), net metering, and net purchase and sale. This study aims to compare these mechanisms with respect to social welfare and to retail electricity rates that include the cost to electric utilities of purchasing residential PV-generated electricity. The study presents a simple microeconomic model that shows, first, that the mechanism that produces the most social welfare is different depending on the amount of reduction in electricity consumption achievable under net metering or net purchase and sale (which are shown to be essentially similar). If the reduction is relatively small, FIT is likely to produce more social welfare than net metering/net purchase and sale; if the reduction is large, the opposite is the case. Second, the model shows that the mechanism that yields the lowest electricity rate is not definite, and differs depending on the homogeneity of households: when households are more homogeneous, the electricity rate under net metering/net purchase and sale is more likely to be higher than that under FIT.

13/01494 Security of supply in electricity markets: improving cost efficiency of supplying security and possible welfare gains

Jacobsen, H. K. and Jensen, S. G. *International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 680–687.

In liberalized markets the ability to maintain security of electricity supply is questioned because security is characterized as a public good. The authors discuss if this property can be modified with changing technology and examine if construction of markets for security can be justified by possible welfare gains. From a welfare perspective it is possible that security levels are too high and obtained with too high costs. Adjusting the effort so that marginal cost for securing supply is at similar levels in generation capacity and in network maintenance could increase welfare even without the need to construct markets. Secondly, a consumer defined average level of security might improve welfare. Finally, different willingness to pay among customers and construction of advanced markets might increase welfare further. The authors argue that several cost and welfare improvements can be achieved without constructing complete markets for security.

13/01495 The impact of the EU ETS on the corporate value of European electricity corporations

Mo, J.-L. *et al. Energy*, 2012, 45, (1), 3–11.

In this research, the impact of the European emissions trading scheme (EU ETS) on the corporate value of European electricity corporations has been measured, and a comparison study of the impact between phase I and phase II of the EU ETS has been performed. To achieve this, a modified multifactor market model has been used to investigate how the development of EU emission allowance (EUA) prices has influenced corporate value. The results indicate that the impact of these has changed much from phase I to phase II. EUA price developments have affected corporate value in opposite directions: in phase I, the increase in EUA prices tended to cause corporate value appreciation, while during phase II, it was more likely to induce depreciation. Second, the corporate value development has been much more sensitive to changes in EUA prices in phase II than in phase I. The causes of the impact change have also been analysed. The conclusion reached has been that the changes have resulted mainly from the adjustment of the EUA allocation policy between phases I and II. Moreover, the effects of corporate efforts to reduce CO₂ emissions on corporate value did not emerge until phase II, when the EUA allocation became more rigorous.

13/01496 Understanding social acceptance of electricity generation sources

Bronfman, N. C. *et al. Energy Policy*, 2012, 46, 246–252.

Social acceptability is a determinant factor in the failure or success of the government's decisions about which electricity generation sources will satisfy the growing demand for energy. The main goal of this study was to validate a causal trust-acceptability model for electricity generation sources. In the model, social acceptance of an energy source is directly caused by perceived risk and benefit and also by social trust in regulatory agencies (both directly and indirectly, through perceived risk and benefit). Results from a web-based survey of Chilean university students demonstrated that data for energy sources that are controversial in Chilean society (fossil fuels, hydro, and nuclear power) fit the hypothesized model, whereas data for non-conventional

renewable energy sources (solar, wind, geothermal and tidal) did not. Perceived benefit had the greatest total effect on acceptability, thus emerging as a key predictive factor of social acceptability of controversial electricity generation sources. Further implications for regulatory agencies are discussed.

13/01497 Valuing fuel diversification in power generation capacity planning

Sunderkötter, M. and Weber, C. *Energy Economics*, 2012, 34, (5), 1664–1674.

Deterministic capacity planning problems in electricity systems can be solved by comparing technology specific long-term and short-term marginal costs. In an uncertain market environment, mean-variance portfolio (MVP) theory provides a consistent framework to balance risk and return in power generation portfolios. Focusing on fuel price risks, MVP theory can be adopted to determine the welfare efficient system generation technology mix. Existing literature on MVP applications in electricity generation markets uses predominantly numerical methods to characterize portfolio risks. In contrast, this article presents a novel analytical approach combining conceptual elements of classical capacity planning models and MVP theory to derive the efficient portfolio structure consisting of an arbitrary number of plant technologies given uncertain fuel prices. For this purpose, the authors provide a static optimization model which allows to fully capture fuel price risks in a mean variance portfolio framework. The analytically derived optimality conditions contribute to a better understanding of the optimal investment policy and its risk characteristics compared to existing numerical methods. Furthermore, they demonstrate an application of the proposed framework and provide results for the German electricity market which has been hardly treated in MVP literature on electricity markets. This article provides easily interpretable analytical optimality conditions for efficient generation portfolios from a societal point of view and therewith contributes to a better understanding of MVP in electricity applications.

07 STEAM RAISING

Boiler operation/design

13/01498 A non-conventional interpretation of thermal regeneration in steam cycles

Bracco, S. and Damiani, L. *Applied Energy*, 2012, 97, 548–557.

The paper aims to contribute to a better understanding of the thermodynamic concept of heat regeneration in steam power plants with a finite number of bleedings. A regenerative Rankine cycle is compared to a complex system (complete hybrid cycle, CHC) composed by one non-regenerative Rankine cycle (hybrid engine cycle, HEC) and more reverse cycles (reverse cycles, RCs), as many as the number of the bleedings, able to pump heat from the condenser to a series of surface feedwater heaters, disposed upstream of the steam plant boiler. The coefficients of performance of the heat pumps are evaluated, and new interesting formulations of the efficiency of the regenerative steam cycle are proposed. In particular a steam cycle with two bleedings is analysed, neglecting heat losses and pressure drops in the boiler and considering irreversibility only along the expansion line of the steam turbine and into the feedwater heaters. The efficiency and the work of the regenerative cycle are compared to the analogous values of the CHC cycle composed by one simple steam cycle (HEC) and two heat pump cycles (RCs), with steam as the working fluid. The two RCs are considered completely reversible and raising heat from the condenser temperature to the bled steam condensing temperature. The paper shows the most significant results of the study in order to analyse the regenerative cycle and the CHC cycle in comparison with the non-regenerative Rankine cycle; in particular, the analysis is focused on the evaluation of the useful work, the heat supplied and the heat rejected for the examined cycles.

13/01499 A study on the rotary steam engine for distributed generation in small size power plants

Antonelli, M. and Martorano, L. *Applied Energy*, 2012, 97, 642–647.

The widespread use of the renewable energies requires compulsorily the development of new technological solutions for the efficient employment of these resources, such as small size, cogenerative power plants. A small volumetric steam engine may be considered an interesting device for an efficient and flexible use the heat generated by biomasses combustion or solar thermal collectors. In effects, this kind of engine may be operated with different kind of fluids, is quite

insensitive to high degrees of humidity at the end of the expansion and is able to manage small volumetric flow rates with no losses in conversion efficiency. This paper shows the development of a rotary steam engine derived from a Wankel internal combustion engine. This engine was taken into account for this use due to its low bulk, vibration and noise running. Moreover, its use as an external combustion engine overrides its typical disadvantages that mainly belong to the combustion phase. The numerical modelling and the experimental tests using compressed air in a first prototype are shown in this paper. The results of the experiments allowed the validation of the model developed and this was employed to carry out a first optimization of the engine by means of the increase of the discharge coefficient of the exhaust valves.

13/01500 An economic assessment of four different boilers for residential heating in Lebanon

Kattan, P. and Ruble, I. *Energy and Buildings*, 2012, 50, 282–289.

An economic analysis comparing four different boiler systems running on olive husks, liquefied petroleum gas (LPG), diesel and electricity used to provide both space and water heating in a standard size apartment located in Lebanon's high mountain area is presented in this study. The results show that the electric boiler system is the most polluting and cost ineffective system with an average energy price of \$0.31/kWh over its life time, compared to only \$0.13/kWh for the olive husk or LPG powered boiler systems, and to \$0.14/kWh for the diesel powered system. Moreover, the current subsidy on diesel oil constitutes a substantial barrier against the deployment of renewable energy as well as other systems running on much cleaner fuels. This paper further presents a financial analysis ranking the different systems in terms of their net present values and suggests measures such as an import tax break and the redirection of the currently existing diesel subsidy towards the olive husk powered system in order to increase the attractiveness of the latter.

13/01501 Biodiesel production from waste frying oils: optimization of reaction parameters and determination of fuel properties

Uzun, B. B. *et al. Energy*, 2012, 44, (1), 347–351.

Alkali-catalysed transesterification of waste frying oils (WFO) was carried out in various conditions to investigate the effects of catalyst concentration, reaction time, methanol/oil molar ratio, reaction temperature, catalyst type (hydroxides, methoxides and ethoxides), and purification type (such as washing with hot water, purification with silica gel and dowex) on the biodiesel yields. The optimum conditions were 0.5% weight of NaOH, 30 min reaction time, 50 °C reaction temperature, 7.5 methanol to oil ratio and purification with hot distilled water. 96% biodiesel yield with ~97% ester content was obtained within in these conditions, and the activation energy was found to be as 11741 J mol⁻¹. The determined specifications of obtained biodiesel according to ASTM D 6751 and EN 14214 standards were in accordance with the required limits. As a conclusion, the present study indicates that WFO derived fuel promises being an alternative for petrodiesel, and could be used in engines without a major modification due to its qualifications.

13/01502 Biomass and central receiver system (CRS) hybridization: volumetric air CRS and integration of a biomass waste direct burning boiler on steam cycle

Coelho, B. *et al. Solar Energy*, 2012, 86, (10), 2912–2922.

Concentrated solar power (CSP) plants generate an almost continuous flow of fully dispatchable 'renewable' electricity and can replace the present fossil fuel power plants for base load electricity generation. Nevertheless, actual CSP plants have moderate electricity costs, in most cases quite low capacity factors and transient problems due to high inertia. Hybridization can help solve these problems and, if done with the integration of forest waste biomass, the 'renewable' goal can be maintained, with positive impact on forest fire reduction. Local conditions, resources and feed in tariffs have great impact on the economic and technical evaluation of hybrid solutions; one of the premium European locations for this type of power plants is the Portuguese Algarve region. Due to the concept innovation level, conservative approaches were considered to be the best solutions. In this perspective, for a lower capital investment 4MWe power plant scale, the best technical/economical solution is the hybrid CRS/biomass power plant HVIB3S4s with CS3 control strategy. It results in a leveled electricity cost (LEC) of €0.146/kWh, with higher efficiency and capacity factor than a conventional 4MWe CRS. A larger 10MWe hybrid power plant HVIB3S10s could generate electricity with positive economic indicators (LEC of €0.108/kWh and IRR of 11.0%), with twice the annual efficiency (feedstock to electricity) and lower costs than a conventional 4MWe CRS. It would also lead to a 17% reduction in biomass consumption (approximately 12,000 tons less per year) when compared with a typical 10MWe biomass power plant – FRB10; this would be significant in the case of continuous biomass price increase.

13/01503 CFD based prediction of erosion rate in large scale wall-fired boiler

Gandhi, M. B. *et al. Applied Thermal Engineering*, 2012, 42, 90–100.
In pulverized coal fired boilers, entrained fly ash particles in the flue gas may cause erosive wear on metal surfaces along the flow field. This can have a significant effect on the operational life of various sections of the boiler (in particular convective heat exchanger tubes). In this work, computational fluid dynamics (CFD) based code FLUENT was used in conjunction with a developed erosion model for a large-scale furnace to understand the flow field and identify the areas likely to be subjected to erosion under various operating conditions. An Eulerian–Lagrangian approach was used to analyse the continuum phase and particle tracking for individual coal particles. The flow field has been thoroughly examined in terms of velocity, particle and temperature profiles along the gas flow path. The data obtained on particle velocities and trajectories have been utilized to predict the extent of erosion in selected areas of the boiler. Predictions have been found to be in good agreement with the published data as well as plant observations for velocities ranging from 15 to 32 m/s showing a deviation of 0.60%. The results obtained from the present work for understanding erosion pattern in boilers are not only of practical significance but also provide a platform for the development of an erosion tool which could assist power utilities in avoiding unnecessary shutdowns and penalties associated with replacement of boiler components.

13/01504 Design of the steam generator in an energy conversion system based on the aluminum combustion with water

Mercati, S. *et al. Applied Energy*, 2012, 97, 686–694.
The paper shows the preliminary design of the superheated steam generator to be used in a novel hydrogen production and energy conversion system based on the combustion of aluminium particles with water. The system is aimed at producing hydrogen and pressurized superheated steam, using the heat released by the $\text{Al-H}_2\text{O}$ reaction. The interest on this type of technology arises because of the possibility of obtaining hydrogen with very low pollutant and greenhouse gas emissions, compared to the traditional hydrogen production systems, such as the steam reforming from methane. The analysis of the combustion chamber and the heat recovery system is carried out by means of a lumped and distributed parameter numerical approach. The multiphase and gas mixture theoretical principles are used both to characterize the mass flow rate and the heat release in the combustion chamber and within the heat exchangers in order to relate the steam generator performance to the system operating parameters. Finally, the influence of the steam generator performance on the whole energy conversion system behaviour is addressed, with particular care to the evaluation of the total power and efficiency variation with the combustion parameters.

13/01505 Use of neural networks for modeling and predicting boiler's operating performance

Kljajić, M. *et al. Energy*, 2012, 45, (1), 304–311.
The need for high boiler operating performance requires the application of improved techniques for the rational use of energy. The analysis presented is guided by an effort to find possibilities for ways energy resources can be used wisely to secure a more efficient final energy supply. However, the biggest challenges are related to the variety and stochastic nature of influencing factors. The paper presents a method for modelling, assessing, and predicting the efficiency of boilers based on measured operating performance. The method utilizes a neural network approach to analyse and predict boiler efficiency and also to discover possibilities for enhancing efficiency. The analysis is based on energy surveys of 65 randomly selected boilers located at over 50 sites in the northern province of Serbia. These surveys included a representative range of industrial, public and commercial users of steam and hot water. The sample covered approximately 25% of all boilers in the province and yielded reliable and relevant results. By creating a database combined with soft computing assistance a wide range of possibilities are created for identifying and assessing factors of influence and making a critical evaluation of practices used on the supply side as a source of identified inefficiency.

08 COMBUSTION

Burners, combustion systems

13/01506 A rapid and accurate method for on-line measurement of straw–coal blends using near infrared spectroscopy

He, C. *et al. Bioresource Technology*, 2012, 110, 314–320.
On-line measurement of biomass–coal blends is very important for developing appropriate subsidy policies for biomass co-firing power generation. Near infrared reflectance spectroscopy (NIRS) was used for on-line qualitative analysis of straw, coal and straw–coal blends and on-line quantitative analysis of straw content of straw–coal blends. A total of 80 straw samples, nine coal samples, 120 straw–coal blends samples with straw content from 70% to 99% (blends1) and 120 straw–coal blends samples with straw content from 1% to 30% (blends2) were prepared. Spectra were obtained using a Thermo Fisher Scientific Antaris Target FT-NIR spectrometer. Linear discriminant analysis method was used for qualitative analysis, correct classification percentages of straw, blends1, blends2 and coal were 89.87%, 79.66%, 94.92% and 100%, respectively. The ratio of standard error of performance to standard deviation (RPD) of quantitative analysis model was 3.52. It is concluded NIRS is a rapid and accurate method for on-line measurement of straw–coal blends.

13/01507 A reduced order full plant model for oxyfuel combustion

Edge, P. J. *et al. Fuel*, 2012, 101, 234–243.
The linkage of models generated in different commercial and/or proprietary software packages is becoming the state of the art for the investigation of power generation applications. Here, a sophisticated process modelling software package, gPROMS, has been linked with a commercial computational fluid dynamics (CFD) code, ANSYS FLUENT version 12, in order to create a reduced-order model for oxyfuel combustion. This is the first such application, and represents a vital step in the evaluation of the impact of oxyfuel operation on a conventional pulverized fuel plant. In order to use existing steam cycle technology, the heat duties to the furnace walls and heat exchangers must match those of conventional combustion. Evidence from earlier experiments at 0.5 MW scale indicate that this is possible; however there is no operating experience of full-scale technology. A full plant model of a 500 MW_e sub-critical UK power station has been adapted for oxyfuel combustion. In order to relate heat transfer in the boiler to the level of oxygen enrichment and recycle ratio, a CFD-generated database of results for air and oxyfuel combustion with an excess oxygen value of 5% in both cases has been developed. Non-linear correlations of heat duties for various heat transfer sections of the plant are developed from the database, and linked to the full plant model. The plant model was then investigated over a range of oxygen concentrations from 25% to 35% by volume at the furnace inlet, which corresponds to a dry recycle ratio range of 66–77%. The aim in this case was to assess the potential for fitting oxyfuel burners to an existing plant. The optimum level of oxygen enrichment is found to be 32% and this corresponds to a recycle ratio of 70%. For these conditions the steam temperatures and heat duties closely match those of the conventional air-firing operation.

13/01508 Combustion behaviours of tobacco stem in a thermogravimetric analyser and a pilot-scale fluidized bed reactor

Yang, Z. *et al. Bioresource Technology*, 2012, 110, 595–602.
Despite its abundant supply, tobacco stem has not been exploited as an energy source in large scale. This study investigates the combustion behaviours of tobacco stem in a thermogravimetric analyser and a pilot-scale fluidized bed (FB). Combustion characteristics, including ignition and burnout index, and combustion reaction kinetics were studied. Experiments in the FB investigated the effects of different operating conditions, such as primary air flow, secondary air flow and feeding rates, on the bed temperature profiles and combustion efficiency. Two kinds of bed materials cinder and silica sand were used in FB and the effect of bed materials on agglomeration was studied. The results indicated that tobacco stem combustion worked well in the FB. When operation condition was properly set, the tobacco stem combustion efficiency reached 94%. In addition, compared to silica sand, cinder could inhibit agglomeration during combustion because of its high aluminium content.

13/01509 Comparative study on differently concentrated aqueous solutions of MEA and TETA for CO₂ capture from flue gases

Schäffer, A. *et al. Fuel*, 2012, 101, 148–153.

Next to IGCC and oxyfuel technology, amine scrubbing is one possible process pursued for industrial-scale CO₂ capture from power plant flue gases. Aqueous solutions of monoethanolamine (MEA) are commonly used for the existing amine scrubbing processes because of their high reaction kinetics during CO₂ absorption. However, the required energy demand for regeneration of the MEA solution is comparably high, requiring improvements in process technology and solvent development. Within this work the results from lab-scale experimental research on the CO₂ absorption from flue gases using differently concentrated aqueous solutions of MEA and triethylenetetramine (TETA) are presented and discussed. The amine content of the solutions was varied in order to show the influence of concentration on CO₂ loading, cyclic capacity and limitations within physical parameters. The equilibrium CO₂ loading of the concentrated amine solutions was obtained at temperatures from 30 to 95 °C using synthetic flue gas with different CO₂ concentrations of up to 15 vol.% CO₂. From these results the cyclic capacities of the different solutions are calculated and discussed with focus on the influence of the amine concentration. Furthermore MEA and TETA will be compared on molar and mass basis specifying the significance of TETA as polyamine and its advantages regarding the scrubbing process.

13/01510 Determination of the activation energies of beef tallow and crude glycerin combustion using thermogravimetry

Crnkovic, P. M. *et al. Biomass and Bioenergy*, 2012, 44, 8–16.

The present study deals with the determination of the activation energy for the thermal decomposition of two renewable fuels: crude glycerin and beef tallow. The activation energies were investigated by using a thermogravimetric (TG) analyser in the temperature range of 25–600 °C in atmosphere of synthetic air. The TG curves of the thermal decomposition process of both samples were divided into several phases and the second, called PH2, was chosen for the kinetic study because it is associated with the combustion ignition. Differential thermal analysis showed an endothermic event at the PH2 region for the crude glycerin corresponding to devolatilization, while for beef tallow, this step presented an exothermic event, called low-temperature oxidation, which is correlated with devolatilization followed by combustion. For the entire PH2, activation energy values for crude glycerin were between 90 and 42 kJ mol⁻¹, while for the beef tallow they ranged from 50 to 113 kJ mol⁻¹. The activation energy values obtained at the pre-ignition stage – conversion between 0 and 0.45 – showed that the crude glycerin with higher values requires an additional energetic support at the start of combustion processes and the beef tallow ignites more easily, presenting lower values. According to the Wolfer's equation, a direct relation between the activation energy and the ignition delay is established and the results of this study provides useful data for the development and design of new combustion chambers and engines when non-traditional fuels are used as feedstock.

13/01511 Experimental studies of flame stability limits of biogas flame

Dai, W. *et al. Energy Conversion and Management*, 2012, 63, 157–161. Flame stability of premixed biogas flame for reference test burner (RTB) was investigated. In this study, six kinds of test gases were used to simulate biogas in which CO₂ volume fraction varied from 30% to 45%. A series of experiments were conducted on two RTBs with different port diameters and at different outlet unburned mixture temperatures. It was found that the lifting and yellow tipping limits show similar trends regardless of the biogas components, port diameters and mixture temperatures. A 'float off' phenomenon could be observed at low gas flow rate and low primary air ratio. Low mixture temperature, small ports and high CO₂ concentration in biogas can lead to the unstable condition of 'float off'. The lifting limits are enhanced with an increase of port diameter or mixture temperature and with a decrease of CO₂ concentration. The yellow tipping limits are extended with an increase of CO₂ concentration and with a decrease of mixture temperature or port diameter. In addition, the lifting limit curve becomes a straight line when semi-logarithmic graph paper is applied. The intercept increases with a decrease of the CO₂ concentration in biogas and with an increase of port diameter or gas temperature.

13/01512 Fireside corrosion of superheaters: effects of air and oxy-firing of coal and biomass

Syed, A. U. *et al. Fuel*, 2012, 101, 62–73.

For pulverized coal-fired power plants, reduced CO₂ emissions can be achieved by increasing the operating temperatures/pressures of the steam systems (which increases the efficiency of power generation), the use of 'carbon-neutral' fuels such as biomass, and/or the implementation of CO₂ capture technologies. The use of small quantities of

biomass fuels (typically up to 5% of the energy content of the fuels) is already widely practised in the UK. As an alternative, oxy-firing pulverized fuel power plants provides a route to enable CO₂ capture technologies to be introduced; but this route also requires the use of higher temperature/pressure steam systems to counteract the efficiency penalty of CO₂ capture and handling systems. All of these options to reduce CO₂ emissions result in significant changes to the operating conditions (e.g. metal temperatures, gas temperatures, gaseous environments and deposits) that are anticipated for superheaters in these power systems. Such changes in operating conditions are expected to result in higher rates of fireside corrosion and so reduce the potential lives of these critical components. This paper reports the results of investigations that have been carried out to assess the effect on fireside corrosion of operating superheaters at higher metal temperatures in power systems using coal/biomass fuels fired with air or oxygen. A series of fireside corrosion experiments has been carried out using the 'deposit recoat' test method to simulate the damage anticipated in different specific environments. Using an alumina-lined controlled-atmosphere furnace, the gaseous and deposit environments were simulated for superheaters in (a) air-fired and (b) oxy-fired (hot gas recycle system variant) power plants using cereal co-product and a UK coal. The corrosion tests were carried out at temperatures of 600 and 650 °C, to represent the metal temperatures anticipated in power plants in the near future. The potential superheater materials used in these tests were T92, 347HFG and HR3C steels, as well as one nickel-based material, alloy 625. The progress of the exposures was monitored using traditional mass change methods. Destructive examinations of the samples were carried out after their exposures, using optical microscopy and SEM/EDX methods to characterize the damage observed. The performance of the materials was determined using dimensional metrology; pre-exposure micrometer measurements and post-exposure image analyser measurements on polished cross-sections. The resulting metal loss distribution data for each sample exposed are being used for the development of statistical models of the fireside corrosion of superheater materials in novel operating environments.

13/01513 Flue gas purification and heat recovery: a biomass fired boiler supplied with an open absorption system

Westerlund, L. *et al. Applied Energy*, 2012, 96, 444–450.

A new technique for energy recovery combined with particle separation from flue gas has been tested in this project. A conventional small boiler for biofuel produces besides heat also particles to the environment through the flue gas. Decreasing the impact on the environment is desirable. Increased efficiency can be obtained if the temperature and water content of the flue gas can be further reduced. Installing an open absorption system in the heat production unit fulfils both these demands. An experimental unit has been built and tested in the last 2 years. The results show a reduction of particles in the flue gas by 33–44% compared to the ordinary system. At the same time the heat production from the unit increased by 40% when fired with wet biofuels.

13/01514 High speed imaging of OH* chemiluminescence and natural luminosity of low temperature diesel spray combustion

Zhang, J. *et al. Fuel*, 2012, 99, 226–234.

This study focused on spray combustion of ultra-low sulfur diesel (ULSD) fuel under low oxygen conditions with low temperature combustion (LTC) mode in an optically accessible constant volume combustion chamber. The ambient oxygen concentration was configured as 10% and 15% to achieve low flame temperature. The ambient gas temperature varied from 800 to 1200 K. High-speed imaging of OH* chemiluminescence and natural luminosity (NL) was used to visualize the instantaneous spray combustion process. The heat release rate was analysed using the transient combustion pressure and the flame structure was studied based on the combustion images. Results show that a higher oxygen concentration case features a shorter ignition delay and higher heat release rate. The LTC mode can be realized by decreasing the oxygen concentration and ambient temperature simultaneously and it features a longer ignition delay, a slower reaction rate, and apparently lower soot radiation heat loss. The visualization results of NL and OH* show that the high temperature reaction occurs mainly in the mid-stream and downstream of the spray combustion, but not in the region very close to the chamber wall. This study validates the LTC process by showing very weak OH* chemiluminescence signal. The results also indicate that in order to realize LTC mode, it is important to control the ambient oxygen and ambient temperature at the same time. By only reducing the ambient oxygen concentration it may not be effective to suppress soot generation.

13/01515 Laminar burning velocity of oxy-methane flames in atmospheric conditionOh, J. and Noh, D. *Energy*, 2012, 45, (1), 669–675.

The laminar burning velocity of oxy-CH₄ flames in atmospheric conditions (300 K and 1 atm) was studied with a lab-scale Bunsen burner. CH chemiluminescence (CH*) was measured, and Schlieren photography was used to derive the laminar burning velocity. The experimental result was compared with the numerical calculation by using a GRI-Mech. ver. 3.0 in a CHEMKIN package. The global equivalence ratio (φ_G) of an oxy-CH₄ mixture varied from $\varphi_G = 0.5$ to 2.0 in 0.1 steps in a laminar flow region. From the observation of the experimental measurements, the structure of laminar premixed flames was composed of a preheating zone, a reaction zone, and a burned gas region. The adiabatic flame temperature (T_{Ad}) was predicted to be 3056 K at $\varphi_G = 1.1$ from the numerical calculation. With the angle method, the laminar burning velocity (S_L) of premixed oxy-CH₄ flames at a normal temperature (300 K) and pressure (1 atm) was measured as $S_L = 2.95$ m/s from Schlieren photographs and $S_L = 2.91$ m/s from CH* images.

13/01516 Large eddy simulations of gaseous flames in gas turbine combustion chambersGicquel, L. Y. M. *et al. Progress in Energy and Combustion Science*, 2012, 38, (6), 782–817.

Recent developments in numerical schemes, turbulent combustion models and the regular increase of computing power allow large eddy simulation (LES) to be applied to real industrial burners. In this paper, two types of LES in complex geometry combustors and of specific interest for aeronautical gas turbine burners are reviewed: (1) laboratory-scale combustors, without compressor or turbine, in which advanced measurements are possible and (2) combustion chambers of existing engines operated in realistic operating conditions. Laboratory-scale burners are designed to assess modelling and fundamental flow aspects in controlled configurations. They are necessary to gauge LES strategies and identify potential limitations. In specific circumstances, they even offer near model-free or DNS-like computations. LES in real engines illustrate the potential of the approach in the context of industrial burners but are more difficult to validate due to the limited set of available measurements. Usual approaches for turbulence and combustion sub-grid models including chemistry modelling are first recalled. Limiting cases and range of validity of the models are specifically recalled before a discussion on the numerical breakthrough which have allowed LES to be applied to these complex cases. Specific issues linked to real gas turbine chambers are discussed: multi-perforation, complex acoustic impedances at inlet and outlet, annular chambers, etc. Examples are provided for mean flow predictions (velocity, temperature and species) as well as unsteady mechanisms (quenching, ignition, combustion instabilities). Finally, potential perspectives are proposed to further improve the use of LES for real gas turbine combustor designs.

13/01517 Numerical investigation Greek lignite/cardoon co-firing in a tangentially fired furnaceKarampinis, E. *et al. Applied Energy*, 2012, 97, 514–524.

The present study presents a three-dimensional numerical model for co-firing lignite and biomass in large-scale utility boilers. The model takes into account the non-spherical form of the biomass particle, which influences the drag coefficient and its devolatilization and combustion mechanisms. Simulations under different co-firing ratios and biomass particle sizes are performed for a 300 MWe pulverized-fuel, tangentially fired boiler located in northern Greece, operating with low quality lignite. Validation of the simulations is performed using plant data for the reference case of lignite combustion. The results obtained, which include temperature and species fields, particle tracks and burnout per burner level and NO_x calculations, provide useful conclusions regarding the maximum allowable biomass particle size and substitution ratio for an efficient boiler operation. In particular, the combustion behaviour of particles from different burner levels suggests the optimum positions for dedicated biomass burners.

13/01518 Reduction of the flue gas recirculation rate in oxycoal processes by means of non-stoichiometric burner operationBlume, M. *et al. Energy*, 2012, 45, (1), 117–124.

Non-stoichiometric burner operation in oxycoal processes has been proposed as a means to control flame temperature and heat exchange on admissible levels similar to air combustion when reducing the recirculation rate, i.e. increasing the oxygen concentration in the oxidizer. Thus, the additional energetic and tangible expenditure of oxyfuel operation compared to conventional air firing can be lowered. Non-stoichiometric burner operation leads to gradual release of combustion enthalpy. On this way lower (adiabatic) flame temperatures are achievable compared to stoichiometric combustion. By combining two or more burners in over- and sub-stoichiometric operation global stoichiometries between $\lambda = 1.10$ –1.15 and low oxygen

concentrations at the combustion chamber outlet are adjustable. In this work the theoretical foundation of staged combustion is presented. Results from measurements on a single flame are given which indicate the controllability of the flame temperature by varying stoichiometry. Gas species concentration profiles normal to the flame axis have been taken. Images obtained from an optical flame surveillance system allow for the visual interpretation of flame stability and shape.

13/01519 Solar-heated rotary kiln for thermochemical energy storageNeises, M. *et al. Solar Energy*, 2012, 86, (10), 3040–3048.

Thermal energy storage (TES) will improve the efficiency and output of solar power plants. TES based on thermochemical cycles is an interesting option as thermochemical cycles can provide high energy storage densities and allow longer heat storage time. The use of multivalent solid oxide reduction–oxidation (REDOX) reactions for thermochemical heat storage is a promising option. Several concepts are feasible for coupling solar energy to the redox reaction. Among those a directly irradiated rotary kiln is one of the most interesting because it is able to provide high mass flow rates and high amounts of active material. A solar-heated rotary kiln was set-up and operated in the solar furnace of DLR for thermal reduction and oxidation of cobalt oxide. The redox material was fed into the reactor batch wise and reduced on-sun at temperatures of about 900 °C and re-oxidized off-sun in the same rotary kiln. Both steps were carried out in an air atmosphere. Thirty cycles were performed with one batch showing no evident degradation of the material. The results confirm that the rotary kiln is a feasible reactor set-up for the solar reduction of metal oxides and, hence, for thermochemical energy storage.

13/01520 Two-dimensional flame temperature and emissivity measurements of pulverized oxy-coal flamesDraper, T. S. *et al. Applied Energy*, 2012, 95, 38–44.

A broadband, RGB, two-colour pyrometry technique for measuring the flame temperature and total emissivity of a two-dimensional image of a coal flame has been developed and used on an oxy-coal flame. The method uses a single, relatively inexpensive, RGB, digital camera. The camera software permits the light intensities of the red, green, and blue light collected for each pixel to be recorded separately. The response of each pixel was calibrated for each colour using a blackbody radiating cavity and a monochromator, which enabled an absolute, broadband emission measurement. The image obtained by the camera was processed to produce a temperature and total emissivity for each pixel. Two spectral emissivity models were explored for use in determining the temperature and emissivity: a Gray model and Hottel and Broughton's soot emissivity model. Significant differences of 7.1% in average temperature and 24.2% in average emissivity were found. While neither model is ideal for the entire coal flame, the Hottel and Broughton model was selected for future image processing because the images and analysis suggested soot was the more dominant emitter for most of the image. Images were obtained in a 150 kW_{th} pulverized-coal reactor at two different mixture oxidizer ratios of O₂/CO₂. The addition of CO₂ decreased the average flame temperature from 2183 to 2022 K and reduced the average emissivity from 0.59 to 0.13. The increase in CO₂ lowered the temperature by increasing the dilution. The increased flow rate caused increased mixing, which reduced soot formation and thus the emissivity.

Fire safety

13/01521 Ozone production from wildfires: a critical reviewJaffe, D. A. and Wigder, N. L. *Atmospheric Environment*, 2012, 51, 1–10.

Tropospheric ozone (O₃) negatively impacts human health and ecosystems, and is a greenhouse gas. Wildfires are a source of tropospheric O₃, and studies show that wildfires are increasing in North America. This study presents a critical review of O₃ production from wildfires focusing on three key topics: the influence of wildfire emissions on O₃ production; the influence of photochemistry on wildfire O₃ production; and regulatory issues associated with wildfire O₃ production in the USA. Observations of $\Delta O_3/\Delta CO$ range from approximately –0.1 to 0.9, and are caused by the interplay of numerous factors including fire emissions, efficiency of combustion, chemical and photochemical reactions, aerosol effects on chemistry and radiation, and local and downwind meteorological patterns. Using average $\Delta O_3/\Delta CO$ ratios for major biomes, the authors estimate global wildfires produce approximately 170 Tg of O₃ per year, which is 3.5% of all global tropospheric O₃ production. Areas of uncertainty in wildfire O₃ production include the net effect of aerosols on chemical and photochemical reactions within a fire plume, the impact of oxygenated volatile organic compounds and nitrous acid on O₃ production, and the

interplay of variables that lead to extreme $\Delta O_3/\Delta CO$ values. Because wildfire frequencies are likely increasing and have been shown to contribute to elevated O_3 at air quality monitoring sites, it is important to better understand the emissions, photochemistry and impacts of these fires.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

13/01522 A divalent quaternary alkyl ammonium salt as the electrolyte for high-energy electric double-layer capacitors
Zheng, C. *et al. Journal of Power Sources*, 2012, 220, 169–172.

A divalent electrolyte salt based on 1,1,4,4-tetramethyl piperazine has been synthesized and applied in electric double-layer capacitors (EDLCs). Traits of the divalent salts have been accessed as well as monovalent quaternary alkyl ammonium salts by the means of galvanostatic charge–discharge tests and ionic conductivity measurements. Compared with monovalent salts, the divalent salts do enlarge the charge storage ability of EDLCs remarkably. However, highly concentrated charge density on the divalent cation has a strong interaction with the organic solvent of propylene carbonate. The adverse effect of this heavy solvation on the performance of EDLCs has been investigated. Moreover, the influence of pore size distribution on the storage ability of these cations at the porous carbon electrode has been addressed.

13/01523 A new composite index of reliability of supply in the industrial systems with distributed generation

Ciric, R. M. and Rajakovic, N. L. J. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 824–831.

Distributed generators (DGs) integrated into distribution networks could affect the host network in number of ways. In this paper an assessment of the impact of the DG continuously operated, which output behaviour is non-stochastic, on the reliability of supply in the industrial networks, is performed. A set of new indices representing impact of DG on the interruption frequency, interruption duration and expected energy not supplied to every single customer, is introduced. In addition, a new composite index compiling the impacts of DG on the overall reliability of supply, including interruption frequency, interruption duration and expected energy not supplied, is proposed. Results obtained from several case studies using real-life industrial network are presented and discussed.

13/01524 A parametric investigation of the chilled ammonia process from energy and economic perspectives

Valenti, G. *et al. Fuel*, 2012, 101, 74–83.

As carbon dioxide anthropogenic generation and climate change appear to be correlated, carbon capture becomes advisable, in particular if applied to coal-fired power plants. The chilled ammonia process (CAP) is a promising technology to be proved for the purpose. Continuing an on-going study, this work examines the integration of ultra-super critical (USC) power plants with CAP, conducting a parametric investigation on the design parameters of the capture block in order to find the optimum from an energy perspective, analysing then in details the power block and estimating ultimately the overall investment and annual costs. The commercial code Aspen Plus and the in-house research code GS are employed. The index SPECCA is adopted as preferred figure of merit of the global performance. With respect to a reference plant of 758 MW_e net electric production at 45.2% net electric efficiency, the carbon capture of 88.4% of the generated CO₂ reduces the net electrical power by 19% and the net electrical efficiency by 8.6% points. The optimum SPECCA is 3.22 MJ/kgCO₂ and the corresponding specific heat duty to the reboiler is 2.46 MJ/kgCO₂. Finally, despite the investment cost of the capture block is about 15% of the power block, the cost of electricity increases from €59.9 to €82.4/MWh_e because of the net electric efficiency penalty, the additional operation and maintenance costs as well as the consumable costs. The resulting cost of avoided CO₂ is €38.6/tCO₂. For comparison, the European Benchmark Task Force (EBTF) computes for conventional MEA a SPECCA of more than 4 MJ/kgCO₂, a cost of electricity of approximately €92/MWh_e and a cost of avoided CO₂ of about €51/tCO₂.

13/01525 Allocation of waste cost in thermoeconomic analysis

Agudelo, A. *et al. Energy*, 2012, 45, (1), 634–643.

In any energy system there are unwanted residual output flows that are necessary to obtain final products. These are known as waste, and represent an exergy loss that has an inherent cost that must be 'charged' to the useful products of the system. Calculation of production costs including waste depends on the allocation of these to productive components. The right way to allocate waste is by identifying the formation process of their cost, since every productive component must be charged only by the part of a waste cost it contributed to. Waste cost allocation is done by means of so called waste cost distribution ratios. Nevertheless, there is no a definitive way to determine these ratios. This study proposes an improved definition of waste cost distribution ratios, based on the premise that waste must be allocated to the productive units that generated their cost. Two energy systems are used as case studies to demonstrate the methodology. It was found that the allocation of waste is significantly improved with the new methodology. Quantitative and qualitative results are satisfactory, since the cost formation process of waste is identified, allowing to perform an improved thermoeconomic analysis.

13/01526 Alternative fuels in cement manufacturing: modeling for process optimization under direct and compound operation

Tsiliyannis, C. A. *Fuel*, 2012, 99, 20–39.

Due to thermal, or exhaust air blower capacity limitations in cement manufacturing processes, the use of alternative fuels may necessitate production volume reductions from the nominal value achieved by fossil fuels, leading to considerable profit reductions. A novel linear algebraic model is presented herein, which isolates combustion stoichiometry invariants from fuel feed flowrates (decision variables). It allows rigorous, though explicit modelling of the integrated kiln–soil mill–fuel mill system, based on fundamental mass and energy balances. It enables assessment of the impact of key operational parameters and inner circuits on production level and kiln emissions, when alternative fuels (AFs) are used. Necessary conditions for balancing the integrated kiln – soil mill – fuel mill process are given in terms of *a priori* known physicochemical parameters and process operational data, both for compound and direct operation. A five-step procedure for process balancing is proposed in order to reap the potential benefits of AF use by selecting a non-inferior AF and conventional fuel mixture. It is shown and demonstrated by an actual case-study, that the enthalpy balance is the clinker production level limiting factor (binding constraint) while the kiln – soil mill offgas exhaust blower may be operated well below capacity.

13/01527 An application of exergoeconomic analysis for a CHP system

Yildirim, U. and Gungor, A. *International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 250–256.

The exergoeconomic analysis is one of the most used exergy sub-methods that combine exergy analysis with economic analysis. Based on a previous exergetic analysis of a combined heat and power (CHP) system which has a total installed electricity and steam generation capacities of 11.52 MW and 9.0 tons/h at 140 °C respectively, this study considers the thermoeconomic analysis in order to provide cost-based information and suggests possible locations for the CHP system improvement. The analysis is based on the specific exergy costing (SPECO) approach and the results show that the specific unit exergy cost of electrical power produced by the CHP system is calculated as \$4.48/GJ. The capital investment cost, the operating and maintenance costs, and the total cost of CHP system as found to be \$649, \$149.60 and \$810.20/h, respectively. The exergoeconomic factor of the diesel engine, heat recovery exchanger, cooling tower exchanger, and cooling exchanger are 79.86%, 41.99%, 87.93% and 55.58%, respectively. The exergoeconomic factor of the compressor is 54.51% while this value is 88.3% for the turbine. The relative cost difference for lubrication oil cooler is calculated to be 57.60% which is the third lowest value after the charge air cooler.

13/01528 An evaluation of the techno-economic potential of co-firing coal with woody biomass in thermal power plants in the south of Brazil

Hoffmann, B. S. *et al. Biomass and Bioenergy*, 2012, 45, 295–302.

Brazil has favourable edaphoclimatic conditions for the cultivation of biomass for energy. On the other hand, the country plans to expand its thermal power park using fossil fuels, including coal. This paper estimates the potential of co-firing biomass from energy forests in power plants based on Brazilian coal (low rank coal) from the main deposits in the south of Brazil. The technical limits of adding woody biomass to a boiler with a fluidized bed running on Brazilian coal is evaluated along with the availability of this biomass in the south of Brazil. Findings indicate that the main technical limit for boilers operating with different mixtures of biomass and coal is the alteration

in the volume of exhaust gas, which varies depending on the percentages of biomass in the co-firing. The limits for biomass availability were based on environmental sustainability and the economic viability of transport. Results indicate that biomass should be available within a radius of around 120 km, which is equivalent to approximately 4,500,000 ha. Only 0.4% of this area would be required to feed a thermal plant of 600 MW_e with 30% biomass.

13/01529 Analysing the potential for implementation of CCS within the European pulp and paper industry

Jönsson, J. and Berntsson, T. *Energy*, 2012, 44, (1), 641–648.

In this paper an approach for analysing the potential for implementation of different technology pathways for the European pulp and paper industry (PPI) is presented. The approach is based on detailed technical research and aggregates the knowledge from previous studies to incorporate the whole European PPI. Thus, the potential for different technology pathways can be estimated on a European level whilst still considering important characteristics of individual mills. The usefulness of the approach was exemplified by applying it to a case study of the potential for introduction of carbon capture and storage (CCS) within the European PPI. The results from the case study show that for the European PPI, CCS has an up-hill road in order to be a viable, large scale alternative for reduction of CO₂ emissions. If CCS is to be introduced in large scale within the European PPI, large biomass-based point sources of CO₂ emissions need to be included when planning for CCS infrastructure and also the infrastructure needs to be built out for clusters emitting <20 MtCO₂/yr.

13/01530 Characterization of PIII textured industrial multicrystalline silicon solar cells

Liu, J. *et al. Solar Energy*, 2012, 86, (10), 3004–3008.

Optimized textured structure is one of the most important elements for high efficiency multicrystalline silicon solar cells. In this paper, in order to incorporate low reflectance nanostructures into conventional industrial solar cells, structures with aspect ratios of about 1:1 and average reflectance of 8.0% have been generated using plasma immersion ion implantation. A sheet resistance of 56.9 Ω/sq has been obtained by adjusting the phosphorous diffusion conditions, while the thickness of the silicon nitride vary in 70–80 nm by extending the deposition time by 100 s. Under the conventional co-firing conditions, a solar cell with efficiency of 16.3% and short-circuit current density 34.23 mA/cm² has been fabricated.

13/01531 Combining optimisation and simulation in an energy systems analysis of a Swedish iron foundry

Mardan, N. and Klahr, R. *Energy*, 2012, 44, (1), 410–419.

To face global competition, and also reduce environmental and climate impact, industry-wide changes are needed, especially regarding energy use, which is closely related to global warming. Energy efficiency is therefore an essential task for the future as it has a significant impact on both business profits and the environment. For the analysis of possible changes in industrial production processes, and to choose what changes should be made, various modelling tools can be used as a decision support. This paper uses two types of energy analysis tool: discrete event simulation (DES) and energy systems optimization (ESO). The aim of this study is to describe how a DES and an ESO tool can be combined. A comprehensive five-step approach is proposed for reducing system costs and making a more robust production system. A case study representing a new investment in part of a Swedish iron foundry is also included to illustrate the method's use. The method described in this paper is based on the use of the DES program QUEST and the ESO tool reMIND. The method combination itself is generic, i.e. other similar programs can be used as well with some adjustments and adaptations. The results from the case study show that when different boundary conditions are used the result obtained from the simulation tools is not optimum, in other words, the result shows only a feasible solution and not the best way to run the factory. It is therefore important to use the optimization tool in such cases in order to obtain the optimum operating strategy. By using the optimization tool a substantial amount of resources can be saved. The results also show that the combination of optimization and simulation tools is useful to provide very detailed information about how the system works and to predict system behaviour as well as to minimize the system cost.

13/01532 Combustion of peanut shells in a cone-shaped bubbling fluidized-bed combustor using alumina as the bed material

Arromdee, P. and Kuprianov, V. I. *Applied Energy*, 2012, 97, 470–482. This paper reports experimental studies on burning peanut shells in the conical fluidized-bed combustor using alumina sand as the fluidizing agent. Prior to combustion tests, hydrodynamic regimes and characteristics of a conical alumina-biomass bed were investigated under cold-state conditions for variable percentage of peanut shells in the mixture and static bed height. With selected particle sizes (300–500 μm) and static bed height (30 cm), alumina ensured bubbling fluidization

regime of the bed at operating conditions specified for firing biomass. Combustion tests were performed at 60 and 45 kg/h fuel feed rates, while ranging excess air from 20% to 80% at a fixed combustor load. Temperature and gas concentrations (O₂, CO, C_xH_y, as CH₄, and NO) were measured along radial and axial directions inside the reactor as well as at stack in order to characterize combustion and emission performance of the combustor for the ranges of operating conditions. For firing 60 kg/h peanut shells, excess air of 40% can be selected as an appropriate value ensuring high, about 99%, combustion efficiency and rather low emissions of CO and NO: 520 and 125 ppm, respectively (both on a dry basis and at 6% O₂). With reducing combustor load, the combustion efficiency and emission characteristics were improved to a little extent. No evidence of bed agglomeration was found during 30-h combustion tests on this conical fluidized-bed combustor using alumina sand as the bed material. However, the timescale effect on the composition of the bed material was found to be substantial.

13/01533 Comparison of mass and energy balances for air blown and thermally ballasted fluidized bed gasifiers

Lysenko, S. *et al. Biomass and Bioenergy*, 2012, 45, 95–108.

The objective of this study was to compare the mass and energy balances for a conventional air-blown fluidized bed gasifier and a ballasted fluidized bed gasifier developed at Iowa State University, USA. The ballasted gasifier is an indirectly heated gasifier that uses a single reactor for both combustion and pyrolysis. Heat accumulated in high-temperature phase change material during the combustion phase is released during the pyrolysis phase to generate producer gas. Gas composition, tar and char contents, cold gas efficiency, carbon conversion, and hydrogen yield per unit biomass input were determined as part of these evaluation. During the pyrolysis phase of ballasted gasification, higher volumetric concentrations of hydrogen and methane were obtained than during air-blown gasification. Hydrogen yield for ballasted gasification was 14 g kg⁻¹ of biomass, which was about 20% higher than that obtained during air-blown gasification. The higher heating value of the producer gas also reached higher levels during the ballasted pyrolysis phase than that of air-blown gasification. Heating value for air blown gasification was 5.2 MJ m⁻³ whereas the heating value for the ballasted pyrolysis phase averaged 5.5 MJ m⁻³, reaching a maximum of 8.0 MJ m⁻³. The ballasted gasifier was expected to yield producer gas with average heating value as high as 15 MJ m⁻³ but excessive use of nitrogen to purge and cool the fuel feeder system greatly diluted the producer gas. Relatively simple redesign of the feeder system would greatly reduce the use of purge gas and may increase the heating values to about 17.5 MJ m⁻³. Higher char production per kilogram of biomass was associated with the ballasted system, producing 140 g kg⁻¹ of biomass compared to only 53 g kg⁻¹ of biomass during air-blown gasification. On the other hand, tar concentrations in the producer gas were 6.0 g m⁻³ for ballasted gasification compared to 11.7 g m⁻³ for air-blown gasification. On balance, carbon conversion was found to be higher for air blown gasification. Cold gas efficiencies were somewhat higher for air-blown gasification compared to ballasted gasification, although the difference did not appear to be significant.

13/01534 Double-effect integration of multicomponent alcoholic distillation columns

Bessa, L. C. B. A. *et al. Energy*, 2012, 45, (1), 603–612.

The growing need to expand the use of renewable energy sources in a sustainable manner, in order to provide energy supply security and to reduce the environmental impacts associated with fossil fuels, finds in bioethanol an alternative economically feasible and with significant potential of expansion. Despite its high energetic demand, distillation is one of the most widely used techniques for separating liquid mixtures. Thus, this work aimed to study distillation columns thermally integrated to produce bioethanol, considering a large amount of minor compounds so that the actual conditions can be better represented. In order to evaluate energy requirements, steady-state simulation of the distillation process was carried out using the software Aspen Plus. As a preliminary step, the simulator results for the current distillation columns configurations were compared with industrial data through analysis of samples collected from mills in operation. Although it has presented, in the case of some minor components, significant deviations, the simulator was able to reproduce satisfactorily the industrial process of alcoholic distillation. The thermally integrated configuration showed good results, with a reduction in the specific steam consumption of 54%. It was observed that minor compounds had a great influence in the steam consumption of the process.

13/01535 Economic evaluation of IGCC plants with hot gas cleaning

Melchior, T. and Madlener, R. *Applied Energy*, 2012, 97, 170–184.

This paper investigates whether coal-fired integrated gasification combined-cycle (IGCC) power plants can be an economically viable future technology for providing less carbon-intensive electricity and heat energy in Germany than today. In the context of CO₂ emission

mitigation in power generation, energy conversion technologies enabling the implementation of carbon capture and storage (CCS) need to be considered. IGCC is such a technology, as it utilizes coal but does not necessarily emit CO₂. This study investigates, from an economic perspective, whether IGCC plants can be an alternative to nuclear and/or conventional coal-fired power plants. The research is based on scenario analysis. The starting point is the expected shut-down of nuclear power stations and outdated coal-fired power plants, as well as the projected evolution of the CO₂ price. The hot gas cleaning option in IGCC plants is of particular interest, as it allows a significant enhancement of the efficiency of the IGCC technology and the use of combined heat and power production (CHP). Corresponding supplementary earnings (including subsidies) are compared with an increase in specific investment costs. Besides hot gas cleaning, the authors also investigate the economic impact of injecting pure CO₂ (separated from the IGCC process) into oilfields, as enhanced oil recovery (EOR) can help to reduce the costs of CO₂ transport and storage. Based on the results from this analysis, it was found that the replacement of currently operating power plants by IGCC facilities is only reasonable under certain circumstances, e.g. for locational reasons. Furthermore, from today's perspective, and due to its various advantages, a complete abandonment of the IGCC technology seems rather unlikely. This analysis of NPVs of total costs indicates that some IGCC designs exist that are less expensive to set up and operate than a conventional reference power plant. The option of injecting CO₂ sequestered from the power plant process into almost depleted oil fields appears attractive for a utility investing in IGCC technology, rendering such a plant configuration as likely cost-competitive. However, with regard to climate change mitigation, the least-cost investment alternative is not necessarily the one with the lowest GHG emissions. Significant cost reductions can be achieved by improving the efficiency or the availability of the plant. Finally, the NPV changes markedly when the heat-to-power ratio is altered, and high ratios are found to be incompatible with NPV minimization.

13/01536 Effects of industrial restructuring on carbon reduction: an analysis of Jiangsu Province, China

Zhang, M. and Huang, X.-J. *Energy*, 2012, 44, (1), 515–526.

From the perspective of the development stage of China's economy and the context in which industrial restructuring is highly promoted in China's twelfth Five-Year Plan, industrial structure adjustment is an effective way to balance economic growth and carbon reduction. The current study analysed the effects of industrial restructuring on carbon reduction in Jiangsu Province. Using input–output analysis, the authors calculated both direct and indirect carbon emissions in 1997, 2000, 2002, 2005 and 2007. The study aimed to classify Jiangsu's industrial sectors by the carbon reducing potential, which was indicated both by carbon reducing efficiency (CRE) and by the amount of carbon reduction, with a 1% decrease in the output of a certain industrial sector. The results indicate that the high CRE of a certain sector might be due to its high direct carbon intensity, indirect carbon intensity or high economic status. Based on the varying contexts, corresponding policy measures were provided. Moreover, export carbon emissions were abundant in sectors with the highest CRE, indicating the production of emissions due to consumption elsewhere.

13/01537 Energy intensity development of the German iron and steel industry between 1991 and 2007

Arens, M. *et al. Energy*, 2012, 45, (1), 786–797.

The iron and steel sector is the largest industrial CO₂ emitter and energy consumer in the world. Energy efficiency is key to reduce energy consumption and greenhouse gas emissions. To understand future developments of energy use in the steel sector, it is worthwhile to analyse energy efficiency developments over the past two decades. This paper analyses the development of the specific energy consumption (SEC) (measured as primary energy use per unit of product) in the German steel sector between 1991 and 2007. The authors found that the total SEC declined by 0.4%/year. Of this 75%, or 0.3%/year, is due to a structural change towards more electric arc furnaces. Energy efficiency improvement accounts for about 25% of the observed change in SEC, or 0.1%/year. Energy efficiency improvements are found, especially in rolling (1.4%/year). The net SEC of blast furnaces decreased due to increased top gas recovery by 0.2%/year per tonne iron. Improvements in other processes were very limited or non-existent. In basic oxygen furnaces (BOF) net SEC increased due to a 60% decrease in BOF gas recovery between 1993 and 2007. In EAF and sinter plants the SEC remained constant or, respectively, even increased by 9% between 1991 and 2007 per tonne sinter.

13/01538 Evaluation of corporate energy management practices of energy intensive industries in Turkey

Ates, S. A. and Durakbasa, N. M. *Energy*, 2012, 45, (1), 81–91.

Turkey is one of a number of countries who still lack a national management standard for energy. Industrial energy consumption accounts for 42% of Turkey's total energy consumption. With the help

of a questionnaire and analytical framework, this paper investigates industrial energy management practice in Turkey and highlights significant bottlenecks and shortcomings of energy intensive industries in terms of energy management application. The survey was carried out as a multiple case study of the Turkish iron, steel, cement, paper, ceramics and textile industries. Outcomes of the questionnaire are evaluated according to the analytical framework which covers company characteristics, regulations, external relations of the companies and internal organizational conditions. After analysing these elements on the basis of a minimum requirement list, it was found that only 22% of the surveyed companies actually practice corporate energy management in Turkey. The main barriers to proper energy management implementation were identified as lack of synergy between the stakeholders, the extent and scope of energy manager courses, and inadequate awareness of and lack of financial support for energy management activities. As a guideline to overcome present obstacles, a set of policy options are offered: strengthening and restructuring of legal and institutional frameworks, promotion of energy efficiency, education, training and capacity building and facilitating implementation of the international energy management standard ISO 50001.

13/01539 Evaluation of electricity saving potential in China's chemical industry based on cointegration

Lin, B. *et al. Energy Policy*, 2012, 44, 320–330.

The purpose of this study is to investigate the future electricity saving potential of China's chemical industry. Applying cointegration, the authors find that there is a long-run equilibrium relationship between electricity intensity and technology, labour, electricity prices and industry structure. The result shows that more active electricity saving policies are objectively required to be implemented in order to reduce the electricity intensity in China's chemical industry as well as to shrink future electricity saving potential. For this purpose, the authors have adopted a scenario analysis method to predict the electricity intensity and the electricity saving amount under two different scenarios. It is found that energy conservation policy provides a continuous impetus for reducing the electricity saving potential. In terms of electricity intensity of the chemical industry, China's intensity is approaching the level in Japan, with the gap narrowing significantly by the year 2020. Finally, based on the elasticities obtained in the long-term equilibrium equation, the paper suggests a range of future policy priorities and directions.

13/01540 Experimental–numerical design of a biomass bubbling fluidized bed gasifier for paper sludge energy recovery

Cordiner, S. *et al. Applied Energy*, 2012, 97, 532–542.

This paper presents the application of a comprehensive approach to the design of small-scale sustainable distributed generation systems with special focus on energy recovery from paper production process sludge. The methodology integrates a detailed fluid-dynamic analysis tool with preliminary experimental analysis on a laboratory scale to guide the design of a prototype bubbling fluidized bed gasifier in the 85 kW power range fitting with small and medium size paper production industries. Preliminary tests show stable operation even for this rather small power scale, and deviation from chemical equilibrium concentration in agreement with literature available data. Energy content in the sludge may be recovered along with a significant reduction of residual volume and mass. The concept may then be used to increase the overall sustainability of paper production.

13/01541 Influence of voltage dips on industrial equipment: analysis and assessment

Honrubia-Escribano, A. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 41, (1), 87–95.

This paper presents a study of industry equipment electrical responses under voltage dips with different magnitude, duration and point-on-wave initiation. The analysis provides electrical sensitive curves for safe and reliable operation based on experimental tests performed over real AC-contactors, ground fault relays, variable speed drives, industrial computers and lighting loads. The presence of a relevant scatter-band where the sensitivity of some equipment in the presence voltage dips responds in a stochastic manner is analysed. The effect of the working temperature of the device is studied as well. A detailed description of the testing procedure is provided, proposing additional voltage dip parameters to characterize the equipment sensitivity in detail. In this way, existing standards and previously published contributions are reviewed and compared with the obtained results. The obtained results are useful for OEMs, utilities, as well as uninterruptible power supply manufacturers; where a more precise counting of equipment failures due to voltage dips is essential for an economic and technical assessment of power quality.

13/01542 International comparisons of energy efficiency in power, steel, and cement industries

Oda, J. *et al. Energy Policy*, 2012, 44, 118–129.

Industrial energy efficiency is of paramount importance both for conserving energy resources and reducing CO₂ emissions. This paper compares specific energy consumption among countries in fossil power generation, steel, and cement sectors. The evaluations were conducted using common system boundaries, allocation, and calculation methods. In addition, the authors disaggregate within sectors, such as with blast furnace–basic oxygen furnace (BF–BOF) steel and scrap-based electric arc furnace (Scrap-EAF) steel. The results reveal that characteristics vary by sub-sector. Regional differences in specific energy consumption are relatively large in the power, BF–BOF steel, and cement sectors. For coal power generation and BF–BOF steel production, continual maintenance and rehabilitation are of key importance. The authors confirm these key factors identified in the previous work on the estimated numerical values. In BF–BOF steel production, corrections for hot metal ratios (pig iron production per unit of BOF crude steel production) and quality of raw materials have a large effect on the apparent specific energy consumption. Available data are not yet sufficient for straightforward evaluations of the steel and cement sectors.

13/01543 Oil price shocks and transportation firm asset prices

Aggarwal, R. *et al. Energy Economics*, 2012, 34, (5), 1370–1379.
The transportation sector is a major user of oil-based energy. Even as oil prices continue to fluctuate greatly, the impact of oil price changes on transportation firms has heretofore not been adequately examined. This paper fills this gap, documenting important new findings based on analysis of over two decades of daily data on large changes in oil prices (oil price shocks). First, while transportation firm returns are influenced negatively by oil price increases, risks are increased more by oil price declines. Second, firm characteristics are important with the market-to-book ratio being the most important firm characteristic, and return on assets, firm size, and the prior run up in prices are also important in influencing oil price related returns, betas, variances, and trading volumes. Third, in the Standard & Poors transportation sub-sector, industry concentration is negatively related to returns, oil price risk, and trading volume, and asymmetrically related to returns and market betas. These new findings enhance the understanding of the asset price impact of oil price shocks and should be of much interest to scholars, corporate executives, money managers, regulators, and policy makers.

13/01544 Optimization of the combustion of SOME (soybean oil methyl ester), B5, B10, B20 and petrodiesel in a semi industrial boiler

Ghorbani, A. and Bazooyar, B. *Energy*, 2012, 44, (1), 217–227.
This paper characterizes combustion of petrodiesel and prevalent soybean oil methyl ester blends (B100, B5, B10 and B20), which were produced through an alkali-based transesterification in PUT, in a semi industrial boiler by determining its efficiency, exhaust emissions and costs. First, the influence of oxygen content of stock gases (by volume percentage) on regular emissions, thermal efficiency and costs (calculated by a cost function) was studied in order to investigate the performance and feasibility of using biodiesel in the boiler. In the next level, a multi-objective optimization method, called cost-based optimization, was represented and optimized the combustion of the fuels. The overall efficiency of the boiler obtained with the different fuels is comparable for the same operating points. Soybean methyl ester and the blends emitted lower emissions than petrodiesel. Results demonstrate that the use of pure biodiesel is not economically feasible in the boiler. The total costs of the boiler obtained with the blends and petrodiesel are quite competitive. B5 is introduced to be the best fuel for using in the boiler. Results also reveal an optimum ('compromise') in total cost of all the fuels in relation to the oxygen concentration of stock gases, which promises a cost saving in the boiler performance.

13/01545 Process integration study of a kraft pulp mill converted to an ethanol production plant – part B: techno-economic analysis

Fornell, R. *et al. Applied Thermal Engineering*, 2012, 42, 179–190.
In a previous study by the authors, energy efficiency measures in a conceptual kraft pulp mill converted to a lignocellulosic ethanol plant were investigated. The results suggested a number of different process designs which would give a substantial improvement in steam economy in the ethanol plant, compared to the original design. In the present study the different process designs are evaluated from an economic point-of-view, in order to determine if energy efficiency measures and increasing by-product sales decrease the production cost of ethanol from this specific process, or if the increased costs related to the implementation of these measures overshadow the benefits from increased by-product sales. The different energy efficiency measures are compared with less capital demanding alternatives (i.e. including low or no energy efficiency improvements) in order to assess the economic benefits of different strategies when converting a kraft pulp mill to ethanol production. The study indicates the economic

importance of considering energy efficiency measures when repurposing a kraft pulp mill to an ethanol plant. It is also shown that, within the context of this study, a larger investment in measures will give better economic results than less capital demanding alternatives (with less improvement in energy efficiency). From an economic and energy efficiency viewpoint many of the suggested process designs will give approximately similar results, therefore the process design should be made based on other criteria (e.g. low complexity, low maintenance).

13/01546 Refrigeration inventory based on CO₂ emissions and exergetic performance for supermarket applications

Sogut, M. Z. *et al. Energy and Buildings*, 2012, 51, 84–92.
In this study, first energy and exergy analysis for supermarket cooling applications having high refrigerant capacity are examined and next, based on these analyses and different gases used, CO₂ emission effect caused by these systems have been evaluated according to two parameters. The study investigated thermodynamic and environmental effects at medium (10/0°C) and low (–35/0°C) evaporation temperatures by reference to a supermarket cooling application with a 4000–5000 m² store size. The study revealed that, refrigerant R-404A is proved to have far worse results than R-22, and proposed alternatives for R-404A, the R-407C and R-152a refrigerants have better average exergetic efficiency ratio, 8.73% and 13.58%, respectively. In addition, according to the TEWI and ICF parameters, emission potentials of these refrigerants were found to be lower being average 27.49% and 25.47 and 34.1% and 51.19, respectively. The study concluded with assessment of how the exergy and environmental effect analyses impact system preference.

13/01547 Regional total factor energy efficiency: an empirical analysis of industrial sector in China

Wang, Z.-H. *et al. Applied Energy*, 2012, 97, 115–123.
The rapid growth of the Chinese economy has resulted in great pressure on energy consumption, especially the energy intensive sector – the industrial sector. To achieve sustainable development, China has to consider how to promote energy efficiency to meet the demand of Chinese rapid economic growth, as the energy efficiency of China is relatively low. Meanwhile, the appeal of energy saving and emission reduction has been made by the Chinese central government. Therefore, it is important to evaluate the energy efficiency of industrial sector in China and to assess efficiency development probabilities. The framework of total factor energy efficiency index is adopted to determine the discrepancy of energy efficiency in Chinese industrial sector based on the provincial statistical data of industrial enterprises above designated size in 30 provinces from 2005 to 2009, with gross industrial output as the output value and energy consumption, average remaining balance of capital assets and average amount of working force as the input values. Besides, in consideration of the regional divide of China, namely eastern, central, and western, and economic development differences in each region, energy efficiency of each region is also analysed in this paper. The results show that there is room for China to improve its energy efficiency, especially western provinces which have large amount of energy input excess. Generally speaking, insufficient technological investment and fail of reaching best scale of manufacture are two factors preventing China from energy efficiency promotion. Based on these findings, some policy implications on the improvement of energy efficiency, particularly for economically underdeveloped regions in China, are also discussed.

13/01548 Simulation and energy optimization of a pulp and paper mill – evaporation plant and digester

Ji, X. *et al. Applied Energy*, 2012, 97, 30–37.
A detailed mathematical process integration model of a pulp and paper mill in the northern Sweden has been developed. The main objective of this work has been set to describe the practical development of the model with particular emphasis on the development of the digester and evaporation plant sub-models. Actual plant measurements have been used to validate the model. By implementing the sub-models into the complete plant model, the influence of different operation parameters on the overall plant performance has been investigated. Case studies regarding how various operational parameters influence the steam consumption, the electricity production and the biomass fuel consumption have been carried out. As a result, several options to save steam and fuel have been identified. For example, if the wood-chips supplied to the digester is preheated from a temperature of 0°C to say 60°C by the use of low-grade residual heat, approximately 5 ton/h of biomass can theoretically be saved. Another case study shows that if the inlet liquor temperature to E4 of the evaporation plant increases from 85 to 105°C, the steam consumption of the evaporation plant decreases from 77 to 66 ton/h and then the biomass fuel consumption decreases from 22 to 17 ton/h.

13/01549 Superstructure-free synthesis and optimization of distributed industrial energy supply systems

Voll, P. *et al. Energy*, 2012, 45, (1), 424–435.

A novel approach is proposed for the superstructure-free synthesis and optimization of distributed energy supply systems (DESS) by exploiting the nature of evolutionary algorithms. Current approaches require the designer to define a superstructure, which subsequently is optimized. In the presented method, the *a priori* specification of a superstructure is avoided: A mutation operator employs generic replacement rules to replace parts of energy supply systems by alternative designs. To minimize both the number of replacement rules and meaningless design alternatives generated during mutation, all energy conversion technologies are classified into the so-called energy conversion hierarchy (ECH). The ECH allows for an efficient definition of all reasonable connections between the regarded components, and the definition of generic replacement rules. Thereby, the hierarchy-supported approach balances richness of the available design space and computational efficiency. In addition, the convenient description of the design space allows for an easy addition of technologies into the optimization problem. The proposed approach thus provides an expandable framework for optimizing DESS. The method is applied to the synthesis of a heating and cooling system. The presented approach efficiently solves retrofit and grassroots design problems. It automatically identifies complex solutions such as trigeneration demonstrating the power of the suggested optimization framework.

13/01550 Technical efficiency, shadow price of carbon dioxide emissions, and substitutability for energy in the Chinese manufacturing industries

Lee, M. and Zhang, N. *Energy Economics*, 2012, 34, (5), 1492–1497. China is the world's largest CO₂ producer and energy consumer. This paper calculates the maximum technically obtainable CO₂ emissions reduction from the efficient use of inputs and estimate the shadow prices of CO₂ emissions in order to assess the potential cost savings deriving from trading emissions among industries by measuring the input distance function for 30 Chinese manufacturing industries. The empirical results indicate that CO₂ emissions could be reduced by as much as 680 million tons in the aggregate. The shadow prices of CO₂ vary from a high of \$18.82 to a low of zero across industries, with an average of \$3.13 per ton. Additionally, the estimated indirect Morishima elasticities of substitution of capital for fossil fuels indicate that the substitutabilities of capital for oil, gas, and coal are higher than the substitutability for labour.

13/01551 The application of CFD modelling to support the reduction of CO₂ emissions in cement industry

Mikulčić, H. *et al. Energy*, 2012, 45, (1), 464–473. The cement industry is one of the leading producers of anthropogenic greenhouse gases, of which CO₂ is the most significant. Recently, researchers have invested a considerable amount of time studying ways to improve energy consumption and pollutant formation in the overall cement manufacturing process. One idea involves dividing the calcination and clinkering processes into two separate furnaces. The calcination process is performed in a calciner while the clinkering process takes place in a rotary kiln. As this is new technology in the cement manufacturing process, calciners are still in the research and development phase. The purpose of this paper is to demonstrate the potential of computational fluid dynamics (CFD) to support the design and optimization of calciners, whose use appears to be essential in reduction of CO₂ emission during cement production. The mathematical model of the calcination process was developed, validated and implemented into a commercial CFD code, which was then used for the analysis. From the results obtained by these simulations, researchers will gain an in-depth understanding of all thermochemical reactions in a calciner. This understanding can be used to optimize the calciner's geometry, to make production more efficient, to lower pollutant formation and to subsequently reduce greenhouse gas emissions.

13/01552 The feasibility of biomass CHP as an energy and CO₂ source for commercial glasshouses

Moreton, O. R. and Rowley, P. N. *Applied Energy*, 2012, 96, 339–346. A techno-economic modelling tool has been developed to examine the feasibility of biomass combined heat and power (CHP) technologies to provide the energy and CO₂ demands of commercial horticultural glasshouses. Using the UK as a case study, energy and CO₂ demands of candidate glasshouse installations on an hourly basis are established using both measured and benchmark datasets. Modelled electrical and thermal generation profiles for a number of commercially available small-scale biomass CHP systems of rated outputs of 0.1–5 MW_e are also derived, and the results of their application within the modelling tool to carry out multi-parametric techno-economic analyses for various operational scenarios are presented. The impacts of both capital grant and generation tariff-based support mechanisms upon economic feasibility are investigated, along with that of variations in feedstock fuel prices. Net CO₂ reductions accruing from the implementation of biomass CHP are also assessed. Finally, technical options, marginal costs and sale tariffs for CO₂ recovery and supply are evaluated for specific scenarios. The results indicate that feasibility is

very sensitive to the relationship between specific biomass CHP power to heat ratios and their match with glasshouse temporal electrical and thermal energy demand profiles, along with economic factors such as specific levels of capital and tariff-based support. With the utilization of currently available financial support mechanisms, biomass CHP offers significant promise for realizing economically viable significant CO₂ emission reductions in this sector.

13/01553 The greenhouse gas mitigation of industrial parks in China: a case study of Suzhou Industrial Park

Liu, L. *et al. Energy Policy*, 2012, 46, 301–307. Climate mitigation at the local level plays a highly important role in greenhouse gas (GHG) emissions mitigation. This research presents a summary of the local efforts in China's ecological industrial parks to assess GHG emissions and identify potential mitigation measures. Through field study and interviews in Suzhou Industrial Park (SIP), in Jiangsu Province, the authors conducted an energy-based GHG emissions inventory for SIP area from 2005 to 2010, with forecasts to 2015. The area emitted a total of 10.30 MMT CO₂e in 2010. Three development strategies including business-as-usual, existing and pending regulations and voluntary mitigating efforts were introduced to estimate the energy-related GHG emissions in 2015. The results projected that emissions will increase to 17.16 Mt in 2015 with no change in policy or practice, but 3.42 Mt of emissions are avoidable with full compliance with national and provincial energy policies (1.41 Mt), as well as local efforts (2.01 Mt). This study furthers the understanding of the potential effectiveness of carbon reduction strategies of industrial parks in China, including the development industrial symbiosis and on-site renewable energy projects.

10 SPACE HEATING AND COOLING/HEAT PUMPS

13/01554 A new operation strategy for CCHP systems with hybrid chillers

Liu, M. *et al. Applied Energy*, 2012, 95, 164–173. Performance and economic efficiency of the combined cooling, heating and power (CCHP) system mainly depend on the system structure, operation strategy and choice of facility capacity. This paper proposes a structural configuration of the CCHP system with hybrid chillers, consisting of a combined electric and absorption chiller, whose electric cooling to cool load ratio varies according to different electric and thermal loads in every hour. A new operation strategy, based on the variational electric cooling to cool load ratio, for the CCHP system with unlimited and limited power generation unit (PGU) capacity is investigated. Given the proposed operation strategy, an optimization algorithm is adopted to determine the optimal PGU capacity. In addition, a case study of a hypothetical hotel in Victoria, BC, Canada is conducted to show the feasibility of the proposed operation strategies. Test results show that, with the proposed operation strategy and corresponding optimal PGU capacity, the new structured CCHP system performs much better than the conventional SP system in all the three evaluation criteria. The annual cost of the CCHP system is reduced more than half of that of the separation production system. In future work, more accurate weather forecast work can lead to more efficient and economical operation. The renewable energy can be introduced into this CCHP system. Solar energy is a good choice and has been widely used in separated houses. With the help of solar energy, the whole CCHP system can be more efficient. Furthermore, it is expected to apply advanced distributed control and networked control technologies to the CCHP system, aiming to achieve improved dynamic performance.

13/01555 Applications of phase change material in highly energy-efficient houses

Rodriguez-Ubinas, E. *et al. Energy and Buildings*, 2012, 50, 49–62. Thermal mass combined with other passive strategies can play an important role in buildings energy efficiency, minimizing the need of space-conditioning mechanical systems. However, the use of lightweight materials with low thermal mass is becoming increasingly common. Phase change materials (PCMs) can add thermal energy storage benefits to lightweight constructions. There are many studies about the use of PCM in buildings, but there are still some difficulties for effective use and practical application of these materials. The study of applications used in real buildings could help us find solutions to these difficulties. This paper analysed different PCM applications presented in highly efficient lightweight construction houses that have participated in the American Solar Decathlon, an international competition organized by the US Department of Energy. These houses have been tested and monitored in Washington DC, place with suitable

climate conditions for short-term thermal storage systems. The study started with a classification of the PCM applications and included an analysis of the systems, materials, switching temperatures, containment and design strategies used to improve the houses energy performance. Also, it included results of numerical simulations and experimentation that the participant team had done, complemented with information available in the literature about similar materials or applications.

13/01556 Assessing performance and controlling operating conditions of a solar driven absorption chiller using simplified numerical models

Marc, O. *et al. Solar Energy*, 2012, 86, (9), 2231–2239.

In cooling buildings, the use of solar energy can save around 50% of primary energy. Many studies have demonstrated the interest of such systems. However, developing and improving reliability of new components, design, control, and implementation remain a major concern. The performances of solar cooling systems are greatly influenced by climatic conditions. Indeed they affect both the driving energy of the chiller and the heat rejection. It is important to mention that internal loads and control strategy also have an impact on energy performances. Therefore, assessing the energy performance during the design phase is a key point in evaluating the economic interest of an installation. Moreover, once the commissioning of the installation is accomplished, there is a need to follow through and ensure its performance, since a large number of malfunctions can affect the quality of the system. Actual performances can be very different from those calculated in the design phase. With this aim, the present article deals with the development of an absorption chiller model used in an existing solar cooling system. This installation includes a single effect absorption chiller with a nominal chilling capacity of 30 kW (EAW LB30 chiller functioning with water and lithium bromide), and it cools four classrooms of a University building in Reunion Island which is situated under a tropical climate. This pilot plant is very good monitored and can thus be used to develop and validate the absorption chiller model. The present paper first recalls the absorption principle and presents the pilot plant, the metrology, and the control strategy. Secondly, the experimental results are analysed and the steady state chiller model and also the identification method are developed. Thereafter, the simplex method is used to determine the design parameters of the machine. Finally, the simulation results are presented. The good agreement between the prediction and the experimental results allows the use of the model not only to design an installation but also to follow and control its performances.

13/01557 Behaviour of the thermal impedance of buried power cables

Papagiannopoulos, I. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 383–387.

The ampacity of power cables depends heavily on their ability to diffuse their resistive heating to their environment. This ability however depends in turn on the characteristics of the material surrounding the power cable. In this work, the concept of thermal impedance is utilized in order to determine the thermal properties of a power cable buried in earth with respect to the burial depth. To that purpose, a theoretical analysis is conducted concerning the calculation of the thermal impedance for the problem under study. Moreover, an experimental setup is used in order to test the remarks obtained by the theoretical analysis concerning the thermal behaviour of the cable.

13/01558 CFD optimization of an immersed particle heat exchanger

De Bellis, F. and Catalano, L. A. *Applied Energy*, 2012, 97, 841–848.

An innovative immersed particle heat exchanger has been recently proposed by the authors: it makes use of very small solid particles as intermediate medium to perform heat transfer between two gas flows at different temperature. The potential of such heat exchanger has been already demonstrated by the authors, who have developed a one-dimensional (1D) model for the computation of the pipe length that ensures a prescribed heat exchange and for the evaluation of the influence of particle characteristics. As completion of the heat exchanger design procedure, this paper provides a numerical procedure for the design optimization of the other geometric parameters defining the heat exchanger, such as diameters and angles of inlet and outlet pipes and particle injection mode. The objective of this numerical optimization is to maximize the heat exchanger efficiency by maximizing the dispersion of the particles falling in countercurrent within the flow. Optimized configurations have been obtained using two different optimization algorithms: these results demonstrate that a numerical optimization based on three-dimensional (3D) thermo-fluid-dynamic simulations is needed to complete the design of the heat exchanger: such approach, which incorporates 3D flow paths and particle trajectories, allows to limit the undesired horizontal shifts of the falling particles near elbows and thus to retrieve a thermal efficiency closer to the theoretical value calculated by the 1D model.

The experimental validation of the employed 3D model has been performed on the initially-guessed configuration, where the 3D features cited above are more evident.

13/01559 Cost and E-level analysis of different dwelling types and different heating systems with or without heat exchanger

Audenaert, A. *et al. Energy*, 2012, 44, (1), 604–610.

Improving energy performance of buildings has become a key goal in managing energy demand. In this context, the European Union produced the Energy Performance of Buildings Directive (EPBD). Flanders (Belgium) converted this directive into the 'Energy Performance and Interior Climate' (EPB). Taking into account this EPB standard, this study will undertake a cost analysis of different heating systems (condensing gas boiler, non-condensing gas boiler, oil boiler and heat pump) and ventilation systems (with or without heat exchanger) and investigate their influence on the E-level. The analysis is performed for three representative types of dwellings in Flanders: a terraced, semi-detached and detached dwelling. The analysis clearly indicates that a condensing gas boiler in combination with the heat exchanger is most advantageous: it is the cheapest heating system and generates the lowest E-level. This makes the condensing gas boiler the best choice for all dwelling types.

13/01560 Dissipative particle dynamics investigation of microencapsulated thermal energy storage phase change materials

Rao, Z. *et al. Energy*, 2012, 44, (1), 805–812.

Phase change material (PCM), has been widely researched in many previous works, shows a good potential for thermal energy storage. The present paper investigated the mesoscopic morphologies and evolution mechanism of microencapsulated phase change materials (MEPCMs) using dissipative particle dynamics (DPD) simulations, which has rarely been performed in PCM related studies. The adequate coarse-grained and Flory–Huggins-type models were used to replace the molecular structures and calculate interaction parameters. The MEPCMs were fabricated with methyl trimethoxysilane (MTMS), 3-aminopropyl trimethoxysilane (APTMS) and n-eicosane in watery environment. The results showed that the simulated final configuration presented a cylindrical structure when the relative amount of water is less than the desired value. The size of the encapsulation decreased with the increasing of water concentration and increased with the increasing of core material concentration. The rational proportion of the components can be optimized or confirmed by the DPD simulations. The research indicates that the DPD simulation is an effective method for understanding the encapsulation process.

13/01561 Energetic, economic and environmental benefits of utilizing the ice thermal storage systems for office building applications

Rismanchi, B. *et al. Energy and Buildings*, 2012, 50, 347–354.

In recent decades, around the world, a huge amount of daytime peak power has been shifted to the off-peak hours by using different types of thermal energy storage systems. However, the contribution of these systems in Malaysia is still minor in comparison with their potential. Therefore, the feasibility and potentiality of employing ice thermal storage (ITS) systems for office building cooling applications is studied to investigate their economic and environmental benefits. The air-conditioning systems in Malaysia are considered as the major energy consumers in office buildings with around 57% share. The economic analysis of the cost benefits is carried out for a system including chiller and storage system. The installation costs are mainly dominated by the total system capacity; hence the study was conducted for a range of 100–2000 tons of refrigeration (TR) (352–7034 kW) for two storage strategy of full storage and load levelling storage strategy. The results indicate that considering the special off-peak tariff rate of \$0.06/kWh for the total system capacities of 500 and 1500 TR (1758 and 5275 kW), the annual cost saving varies from \$230,000 to \$700,000 and from \$65,000 to \$190,000 for full storage and load levelling storage strategy, respectively. The overall results show that the full storage strategy can reduce the annual costs of the air conditioning system by up to 35% while this reduction is limited to around 8% for a load levelling strategy. The comparison study reveals that for the full storage strategy the payback period varies between 3 and 6 years while the payback period for the load levelling strategy varies between 1 and 3 years. It was concluded that the ITS system can play an important role in consuming the natural resources in a more efficient, economical and environmentally benign way by changing the electricity consumption pattern to overcome the disparity between energy generation and energy demand.

13/01562 Entropy generation analysis of fan-supplied gas cooler within the framework of two-stage CO₂ transcritical refrigeration cycle

Li, W. *et al. Energy Conversion and Management*, 2012, 62, 93–101.

Optimization design of heat exchangers based on entropy generation analysis is critical to improve the efficiency of CO₂ refrigeration systems. However, most of the previous studies in this field were focused on individual components that are isolated from the entire system. Little has been done on the component analysis within the framework of entire refrigeration cycle. To probe this important issue, the entropy generation analysis is performed in this study on the fan-supplied gas cooler within a two-stage CO₂ refrigeration system. The optimum circuit length is found by investigating the influences of geometrical parameters such as tube spacing, fin density and tube diameter on the heat transfer rate and entropy generation number of the gas cooler. The designed fan-coil is then put into the frame of the two-stage refrigeration cycle and its energy performance and exergy performance are both evaluated on the system level. The results show that the analysis with isolated gas cooler can lead to overestimated or unrealistic predictions on the heat transfer performance compared to the analysis within the framework of entire cycle.

13/01563 Exergy metrication of radiant panel heating and cooling with heat pumps

Kilkis, B. *Energy Conversion and Management*, 2012, 63, 218–224. Radiant panels are known to be energy efficient sensible heating and cooling systems and a suitable fit for low-exergy buildings. This paper points out the little known fact that this may not necessarily be true unless their low-exergy demand is matched with low-exergy waste and alternative energy resources. In order to further investigate and metricate this condition and shed more light on this issue for different types of energy resources and energy conversion systems coupled to radiant panels, a new engineering metric was developed. Using this metric, which is based on the rational exergy management model, true potential and benefits of radiant panels coupled to ground-source heat pumps were analysed. Results provide a new perspective in identifying the actual benefits of heat pump technology in curbing CO₂ emissions and also refer to IEA Annex 49 findings for low-exergy buildings. Case studies regarding different scenarios are compared with a base case, which comprises a radiant panel system connected to a natural gas-fired condensing boiler in heating and a grid power-driven chiller in cooling. Results show that there is a substantial CO₂ emission reduction potential if radiant panels are optimally operated with ground-source heat pumps driven by renewable energy sources, or optimally matched with combined heat and power systems, preferably running on alternative fuels.

13/01564 Experimental investigation on performance of transcritical CO₂ heat pump system with ejector under optimum high-side pressure

Xu, X. X. *et al. Energy*, 2012, 44, (1), 870–877. Since the fixed ejector cannot adjust the optimum high-side pressure, the adjustable ejector is designed and built based on a transcritical CO₂ heat pump system model results. The adjustable ejector is subjected to electrical pulses through the stepper motor which drives needle forward or backward movement to change the nozzle throat area for the optimum high-side pressure. Experimental investigation of the transcritical CO₂ heat pump cycle with adjustable ejector is presented. The effects of the high-side pressure on the system performance are analysed. A control strategy for maximum COP_h is developed by correlating the CO₂ pressure and temperature at the gas cooler exit, yielding the ejector optimum high-side pressure control equation. Experiment results show that there exist maximum values for heating performance coefficient and heat capacity with increasing high-side pressure. The increased high-side pressure has a positive effect on the system performance and outweighs lower ejector efficiencies. The ejector efficiency is mainly distributed within range of 20–30%.

13/01565 Finite element calculation and energy analysis of electric preheating in direct buried heating pipeline

Ying, W. *et al. Energy and Buildings*, 2012, 52, 93–98. The method of electric preheating pipelines in the district heating system was introduced. The thermal–structural coupling analysis was used for the electric preheating insulation pipe by ANSYS. The three-dimensional transient finite element model of electric preheating pipeline in the district heating system is established according to the principle of thermology and mechanics. Through the experiment, the result obtained with experiments agrees with the finite element result. And it makes theoretical deduction and experimental analysis to electric preheating method. By analysing energy, the current of electric preheating has been obtained. Basing on the test data of measuring current of several heating pipelines, these formulas have advantage of easy calculation, wide applications, high reliability and less error rate.

13/01566 Fluid flow and heat transfer in a latent thermal energy unit with different phase change material (PCM) cavity volume fractions

Ye, W.-B. *et al. Applied Thermal Engineering*, 2012, 42, 49–57.

In present work, the effects of different cavity volume fractions of phase change material (PCM) on fluid flow and heat transfer behaviour in a latent thermal unit are studied numerically. The commercial computational fluid dynamics (CFD) package, Fluent, is used for the numerical solution based on transient conjugate heat transfer. The numerical results have been verified and validated against numerical and experimental data available in published literature. The volume expansion ratio, the time of complete thermal storage, heat flux, liquid fraction, velocity and temperature fields are investigated for the range of PCM cavity volume fractions ($\phi_{\max}$) from 35% to 95%. It is noted that a vortex (as a heat transfer enhancer) is present near the heating plate wall for the PCM cavity volume equal to 85%. It is found that the volume expansion ratio decreases as $\phi_{\max}$ increasing, whereas the time for complete energy storage increases. Further, the correlations of the volume expansion ratio and the time of complete thermal storage are developed as a function of $\phi_{\max}$. The detailed knowledge regarding interface heat transfer rate provides a deeper understanding the heat transfer mechanisms.

13/01567 General correlation of a natural convective heat sink with plate-fins for high concentrating photovoltaic module cooling

Do, K. H. *et al. Solar Energy*, 2012, 86, (9), 2725–2734. Thermal resistance correlation as a design tool of a natural convective heat sink with plate-fins for concentrating photovoltaic (CPV) module cooling is suggested. For this purpose, extensive experimental investigations are performed for various heat sink geometries, input power, as well as inclination angle. From the comparison between the proposed general correlation and the previous studies, it is shown that the proposed correlation predicts well the effects of inclination angle and fin spacing on the thermal performance of the natural convective heat sink with plate-fins. Also, optimal fin spacing strongly depends on the temperature difference as well as the inclination angle. The optimal fin spacing is significantly changed when the inclination angle is larger than 70°.

13/01568 Improving the performance of the down-hole heat exchanger at the Alpine Motel, Rotorua, New Zealand

Steins, C. *et al. Geothermics*, 2012, 44, 1–12. The township of Rotorua is situated on top of a shallow geothermal reservoir. The resource is easily accessible and is commonly used for district heating. Excessive exploitation in the 1970s and 1980s resulted in the decline of the unique thermal natural features in the Whakarewarewa geysers area, which prompted the government to set a production moratorium within a 1.5 km area around the geysers. The production wells at the Alpine Motel had to be abandoned in 1987 and the motel resorted to gas-fired heaters. A down-hole heat exchanger (DHE) was used to supply the required heat, but only 22% of the heat demand was produced. Air lifting was implemented to improve the performance of the DHE, which resulted in a 125% increase in heat output. This significant increase in heat output compared to early trials was discussed. Recommendations are given to further improve the DHE performance.

13/01569 Investigation on performance of variable geometry ejectors for CO₂ refrigeration cycles

Liu, F. *et al. Energy*, 2012, 45, (1), 829–839. This paper presents a comprehensive study on a controllable two-phase flow ejector component efficiencies and ejector performances in transcritical CO₂ refrigeration cycles. A two-phase flow ejector expansion model was developed and experimentally validated. A method of determining the efficiencies of ejector motive nozzle, suction nozzle, and mixing section based on the measured performance data external to the ejector was developed. It was found that motive nozzle efficiency decreases as ejector throat area decreases, and that suction nozzle efficiency is affected by outdoor air temperature. Empirical correlations of ejector component efficiencies were reduced. Parametric modelling study results show that the operation of an ejector reaches its optimum performance at ejector throat diameter approximately of 2.3 mm, mixing section constant-area diameter approximately of 3.5 mm, and diffuser diameter ratio a little bit larger than 2. Higher efficiencies of motive nozzle and suction nozzle as well as higher motive nozzle inlet pressure result in better ejector performances in certain ranges of motive nozzle throat diameter and mixing section constant-area diameter.

13/01570 Minimisation of a heat exchanger networks' cost over its lifetime

Nemet, A. *et al. Energy*, 2012, 45, (1), 264–276. The optimal design of heat exchanger networks (HENs) has a great influence on the profitability of a plant. The optimization is based on trade-offs between investment and operational cost. The full lifetime of the HEN and future utility prices have to be considered rather than optimizing HEN on a yearly basis using current utility prices. Single-period optimization and synthesis models for HENs reflect current

utility prices only. These prices can fluctuate rather quickly and the optimal solution may be very different from a year to year. Deterministic and stochastic multi-period mixed-integer non-linear programming (MINLP) models for HEN synthesis have been developed to account for future price projections, where the utility cost coefficients are forecasted for the lifetime of the process. An optimal design is then determined for each projection and these designs are compared against a design with fixed current prices by applying the incremental net present value and other economic measures. In case studies the difference between utility consumption, using previous optimization methods and new, were significant; e.g. in case study 2 the utility savings were 18.4% for hot and 32.6% for cold utility yielding an increase of the net present value by 7.8%.

13/01571 Model predictive control technologies for efficient and flexible power consumption in refrigeration systems

Hovgaard, T. G. *et al. Energy*, 2012, 44, (1), 105–116.

Considerable amounts of energy are consumed in supermarket refrigeration systems worldwide. Due to the thermal capacity of refrigerated goods and the rather simplistic control most commonly applied, there is a potential for distributing the system load over time in a more cost-optimal way. This paper describes a novel economic-optimizing model predictive control (MPC) scheme that reduces operating costs by utilizing the thermal storage capabilities. A non-linear optimization tool to handle a non-convex cost function is utilized for simulations with validated scenarios. In this way the authors explicitly address advantages from daily variations in outdoor temperature and electricity prices. Secondly, they formulate a new cost function that enables the refrigeration system to contribute with ancillary services to the balancing power market. This involvement can be economically beneficial for the system itself, while crucial services can be delivered to a future flexible and intelligent power grid (smart grid). Furthermore, the authors discuss a novel incorporation of probabilistic constraints and second-order cone programming with economic MPC. A finite impulse response formulation of the system models allows us to describe and handle model as well as prediction uncertainties in this framework. This demonstrates the means for robustifying the performance of the controller.

13/01572 Optimising PCM thermal storage systems for maximum energy storage effectiveness

Amin, N. A. M. *et al. Solar Energy*, 2012, 86, (9), 2263–2272.

A new performance parameter for PCM thermal storage systems, the energy storage effectiveness, is defined. This parameter can be used to optimize the design of any PCM thermal storage system to maximize the use of the thermal storage media. The paper presents results of a parametric study using an experimentally validated numerical model for PCM encapsulated in plates. The results are used to calculate the energy storage effectiveness which is ultimately used to optimize the useful energy that can be stored in the PCM thermal storage system. The energy storage effectiveness is also used to compare the useable storage capacity of the PCM relative to a sensible energy storage system.

13/01573 Phase change material (PCM) based thermal management system for cool energy storage application in building: an experimental study

Tyagi, V. V. *et al. Energy and Buildings*, 2012, 51, 248–254.

In the present work, the thermal management system (TMS) for cool energy storage has been designed and studied experimentally. A prototype test room was designed to investigate the performance study of the thermal management system (TMS) with different operation conditions to maintain the temperature in under comfort range. The room air temperature, ambient temperature and PCM temperature at different locations were measured continuously. The TMS has 60 PCMs based high density polyethylene panels. The experimental room temperature was maintained between 22 and 24°C during the cool energy storage in TMS. The different heat loads were used to know the real performance of TMS system for maintaining the experimental room temperature. The results of the study showed that there is a significant variation in the time duration to exceed the thermal comfort temperature with different heat loads. The experimental room temperature was maintained at 09:00, 3:30 and 2:30 in the presence of thermal management system with different heat loads. In other words, the temperature profile of the test room with room heater of 1 kW is found to be longest when it is used in the presence of TMS, while it is found to be the shortest in the case of 3 kW room heater without TMS. Thus it can be concluded that the TMS can maintain the room air temperature for long time even with an active heating load and hence, the TMS used in this study is a good alternative for both passive and active building space conditioning applications.

13/01574 Polyurethanes as solid–solid phase change materials for thermal energy storage

Alkan, C. *et al. Solar Energy*, 2012, 86, (6), 1761–1769.

Polyurethane polymers (PUs) have been synthesized as solid–solid phase change materials for thermal energy storage using three different kinds of diisocyanate molecules and polyethylene glycols (PEGs) at three different molecular weights. PEGs and their derivatives are usually used as phase change units in polymeric solid–solid phase change materials due to the hydroxyl functional groups. PEGs of 1000, 6000 and 10,000 g/mol average molecular weight are used as the working element and hexamethylene, isophorone and toluene diisocyanates are used as the hard segment at the backbone. The effects of molecular weight of PEG and type of diisocyanate on the thermal energy storage properties have been discussed. Only two of the produced polymers show solid–liquid phase change as the rest show solid–solid phase transitions. The produced PUs with a solid–solid phase transitions have potential to be used in thermal energy storage systems.

13/01575 Simulated transient dynamics and heat transfer characteristics of the water boiler nuclear reactor – SUPO – with cooling coil heat extraction

Buchan, A. G. *et al. Annals of Nuclear Energy*, 2012, 48, 68–83.

The term ‘water boiler’ reactor refers to a type of aqueous homogeneous reactor (AHR) that was designed, built and operated by Los Alamos in the 1940s. This was the first type of liquid fuelled reactor and the first to be fuelled with enriched uranium. For security reasons the term ‘water boiler’ was adopted and three versions were built: LOPO (for low power), HYPO (for high power) and SUPO (for super power) which were spherical-shaped reactor vessels. The name was appropriate as the reactors appeared to boil although this was actually due to the release of radiolytic gas bubbles; although SUPO was operated during some studies close to the boiling point of uranyl nitrate. The final water boiler SUPO was operated almost daily as a neutron source from 1951 until its deactivation in 1974, after 23 years of safe, reliable operation. Many of the key neutron measurements needed in the design of the early atomic weapons were made using LOPO, HYPO and SUPO. More recently SUPO has been considered as a benchmark for quasi-steady-state operation of AHRs with internal cooling structures. This paper presents modelling and analysis of the coupled neutronic and fluid time dependent characteristics of the SUPO reactor. In particular the quasi-steady-state dynamics of SUPO have been investigated together with its heat transfer characteristics. In the simulations presented the SUPO reactor is modelled using the spatially dependent neutron/multiphase CFD simulation tool, FETCH, at a quasi-steady-state power of 25 kW. SUPO also possessed a cooling coil system that fed cooling water through the reactor for the extraction of the fission and decay heat. This cooling system, and the heat extraction, is modelled in the simulations using a new sub-modelling approach that is detailed here. The results from this simulation, such as gas fraction, gas generation rate, coolant rate and average temperature, are compared against the available experimental information.

13/01576 Soil thermal conductivity prediction for district heating pre-insulated pipeline in operation

Perpar, M. *et al. Energy*, 2012, 44, (1), 197–210.

The research refers to the district heating (DH) system in Ljubljana, which includes 245 km of highly diversified pipelines. The purpose of this study was to determine the effect of the soil thermal conductivity coefficient (λ_s) on the heat loss from pre-insulated pipes during operation. Pipeline geometry, material properties (particularly insulation and soil thermal conductivity) and time-dependent data on supply, return and environs temperature were considered. Measurements of temperature, moisture, thermal conductivity of soil and heat flux through the soil were carried out at the chosen locations on the pre-insulated pipeline. In addition, laboratory measurements were conducted on the soil samples from this site in order to determine the soil density, specific heat and thermal diffusivity. For the evaluation of heat loss, transient and steady-state numerical simulations of the soil temperature field were performed. In transient simulations, in addition to the impact of environment temperature, the influence of supply and return temperatures was taken into account. A method for λ_s prediction during pipeline operation is presented. The algorithm is based on a comparison of the measured (Θ_{exp}) and simulated (Θ_{sim}) temperatures in the selected period of time with the same boundary conditions.

13/01577 Study of the influence of roof insulation involving local materials on cooling loads of houses built of clay and straw

Toguyeni, D. Y. K. *et al. Energy and Buildings*, 2012, 50, 74–80.

This paper presents an investigation of the influence of local insulated roofing materials used in Burkina Faso on air conditioning loads of typical individual houses located in dry tropical climates. The walls are made of a composite clay–straw mixture whereas the insulated

materials are made of red wood, white wood, and two assembled insulated panels. The thermophysical properties of the insulating materials as well as the clay-straw composite have been studied, utilizing an experimental apparatus based on the hot plate method. The values of the thermophysical properties obtained are in the same range as those published in the literature. The house has also been modelled using TRNSYS together with the climatic data of Ouagadougou. This simulation shows that the clay-straw mixture reduces the air conditioning load by about 8% compared to clay-walled houses. As for the roof, the study indicates the influence of the insulated materials on the air conditioning load. Hence, a 1.5 cm thick insulator made of redwood induces a saving of energy about 6.2% and 12.1% for an insulation panel made of natural fibre and a lime-cement mixture on the air conditioning load.

13/01578 Thermal and mechanical properties of nitrate thermal storage salts in the solid-phase

Iverson, B. D. *et al. Solar Energy*, 2012, 86, (10), 2897–2911. Implementation of molten salt compounds as the heat transfer fluid and energy storage medium provides specific benefits to energy collection and conversion. Nitrate salts have been identified as a strong candidate for energy transfer and storage and have been demonstrated for use in these applications over time. As nitrate salts have solidification temperatures above ambient, concern for recovery from salt freezing events has instigated efforts to understand and predict this behaviour. Accurate information of salt property behaviour in the solid-phase is necessary for understanding recovery from a freeze event as well as for phase change thermal energy storage applications. Thermal and mechanical properties for three representative salts (solar salt, HITEC salt, and a Na–K–Li–Ca nitrate salt; spanning the range of liquidus temperatures from approximately 90–240 °C), have been obtained. These properties include: specific heat, coefficient of thermal expansion, thermal conductivity, latent heat of fusion, compressive strength, tensile strength, Young's modulus and Poisson's ratio. Specific heat, thermal conductivity and latent heat of fusion were measured using differential scanning calorimetry. Temperature was not observed to have a significant effect on tensile strength using an indirect tensile test (Brazilian test). Peak stress and Young's modulus (both from unconfined compressive strength testing) were shown to decrease while Poisson's ratio increased with increasing temperature.

13/01579 Thermal design of a tray-type distillation column of an ammonia/water absorption refrigeration cycle

Zavaleta-Aguilar, E. W. and Simões-Moreira, J. R. *Applied Thermal Engineering*, 2012, 41, 52–60.

The goal of this paper is to present an analysis of a segmented weir sieve-tray distillation column for a 17.58 kW (5 TR) ammonia/water absorption refrigeration cycle. Balances of mass and energy were performed based on the Ponchon–Savarit method, from which it was possible to determine the ideal number of trays. The analysis showed that four ideal trays were adequate for that small absorption refrigeration system having the feeding system to the column right above the second tray. It was carried out a sensitivity analysis of the main parameters. Vapour and liquid pressure drop constraint along with ammonia and water mass flow ratios defined the internal geometrical sizes of the column, such as the column diameter and height, as well as other designing parameters. Due to the lack of specific correlations, the present work was based on practical correlations used in the petrochemical and beverage production industries. The analysis also permitted to obtain the recommended values of tray spacing in order to have a compact column. The geometry of the tray turns out to be sensitive to the charge of vapour and, to a lesser extent, to the load of the liquid, being insensitive to the diameter of tray holes. It was found a column efficiency of 50%. Finally, the paper presents some recommendations in order to have an optimal geometry for a compact size distillation column.

13/01580 Thermal simulation of composite high conductivity laminated microencapsulated phase change material (MEPCM) board

Darkwa, J. and Su, O. *Applied Energy*, 2012, 95, 246–252. In this paper, three-dimensional geometric models have been developed to evaluate the particle distribution effect on the thermal performance of a composite high-conductivity laminated microencapsulated phase change material (MEPCM) board. For the purpose of comparison three geometric configurations (rectangular, triangular and pyramidal) were considered for the distribution network. Copper foam was used as the base material for fixing the positions of the MEPCM particles and to enhance the thermal conductivity of the composite laminated board. The simulation results show that the thermal response times for the rectangular and triangular geometries were about half that of the pyramidal geometry during cooling and heating processes of the board. Even though there were no significant differences in their effective thermal conductivities, the values were more than 10 times that of pure MEPCM but suffered from a reduction

in energy storage capacities by about 48%. Other methods of enhancing both thermal conductivity and energy storage are therefore encouraged.

13/01581 Thermo hydraulic analysis of narrow channel effect in supercritical-pressure light water reactor

Zhou, T. *et al. Annals of Nuclear Energy*, 2012, 47, 234–241.

The size of the gap between fuel rods has important effects on flow and heat transfer in a supercritical-pressure light water reactor. Based on thermal analysis at different coolant flow rates, the reasonable value range of gap size between fuel rods is obtained, for which the maximum cladding temperature safety limits and installation technology are comprehensively considered. First, for a given design flow rate of coolant, thermal hydraulic analysis of supercritical pressure light water reactor with different gap sizes is provided by changing the fuel rod pitch only. The results show that, by means of reducing the gap size between fuel rods, the heat transfer coefficients between coolant and fuel rod, as well as the heat transfer coefficient between coolant and water rod, would both increase noticeably. Furthermore, the maximum cladding temperature will significantly decrease when the moderator temperature is decreased but coolant temperature remains essentially constant. Meanwhile, the reduction in the maximum cladding temperature in the inner assemblies is much larger than that in the outer assemblies. In addition, the maximum cladding temperature could be further reduced by means of increasing coolant flow rate for each gap size. Finally, the characteristics of narrow channels effect are proposed, and the maximum allowable gap between fuel rods is obtained by making full use of the enhancing narrow channels effect on heat transfer, and concurrently considering installation. This could provide a theoretical reference for supercritical-pressure light water reactor design optimization, in which the effects of gap size and flow rate on heat transfer are both considered.

13/01582 Thermocline stability criterions in single-tanks of molten salt thermal energy storage

Qin, F. G. F. *et al. Applied Energy*, 2012, 97, 816–821.

Thermal storage with molten salt is considered to be an important subsystem for solar thermal power stations due to the fluctuation of sunshine over time. A molten salt thermal storage tank, in which the fluid is stratified in temperature with 'hot' on the upper level and 'cold' in the lower level due to the density difference of the fluids (criterion 1), is preferred for the system efficiency. Porous media, such as quartzite rock or silica sand, are used to fill the tank in order to reduce the inventory of the molten salt and manage the mixing between the hot and cold molten salt, so as to form a stable layer of thermocline. However, in the flow of molten salt, either the hot fluid displaces the cold one or vice versa, phenomena of viscous fingering and/or channelling are likely to occur, which may disturb the stability of the thermocline, resulting in an over widened temperature transitional zone. To circumvent the problems, criterions are proposed in this work based on the analysis of Darcy's flow in porous medium, i.e. criterion 2, when hot molten salt displaces cold molten salt, the flow velocity must be under the critical value (v_c); criterion 3, when cold molten salt displaces hot molten salt from the top down, though this is unusual, the flow velocity must exceed a critical value (w_c); and criterion 4, in the thermocline region, if the mobility ratio is less than 1, displacement is stable, otherwise it is unstable. Criterion 1 concerns the hydrostatics factor, i.e. density and gravity. Criteria 2–4, however, take hydrodynamics into consideration as well, which involve velocity, density and viscosity of the fluid, and porosity and permeability of the porous medium.

13/01583 Thermodynamic analysis of an absorption refrigeration system with ionic-liquid/refrigerant mixture as a working fluid

Kim, Y. J. *et al. Energy*, 2012, 44, (1), 1005–1016.

Thermodynamics of an ionic-liquid (IL) based absorption refrigeration system has been numerically analysed. It provides an alternative to the normally toxic working fluids, such as the ammonia in conventional absorption systems. The use of ILs also eliminates crystallization and metal-compatibility problems of the water/LiBr system. Mixtures of refrigerants and imidazolium-based ILs are theoretically explored as the working fluid pairs in a miniature absorption refrigeration system, so as to utilize waste-heat to power a refrigeration/heat pump system for electronics cooling. A non-random two-liquid (NRTL) model was built and used to predict the solubility of the mixtures. Saturation temperatures at the evaporator and condenser were set at 25 and 50 °C, respectively, with the power dissipation of 100 W. Water in combination with [emim][BF₄] (1-ethyl-3-methylimidazolium tetrafluoroborate) gave the highest coefficient of performance around 0.9. The refrigerant/IL compatibility indicated by the circulation ratio, alkyl chain length of the IL, and thermodynamic properties of the refrigerants, such as latent heat of evaporation were proven to be important factors in determining the performance of the absorption

system. The negative effect of high viscosity was mitigated by dilution of the IL with the refrigerant and the use of slightly larger microfluidic channel heat exchangers.

13/01584 Thermodynamic study of an EFGT (externally fired gas turbine) cycle with one detailed model for the ceramic heat exchanger

de Mello, P. E. B. and Monteiro, D. B. *Energy*, 2012, 45, (1), 497–502. The externally fired gas turbine (EFGT) cycle has been considered as an option to burn biomass in gas turbines. One key element on the implementation of one EFGT cycle is the high-temperature heat exchanger (HTHE) necessary to support the high temperatures of operation. The performance of the HTHE, its effectiveness and pressure drop imposed to the gas flow, may have significant influence over the thermal efficiency of the EFGT cycle. The simulations of the EFGT cycle presented herein use correlations for the pressure drop and heat transfer of one ceramic heat exchanger of the plate and fin type, evaluated numerically. The results obtained show that the type of ceramic heat exchanger simulated presents adequate performance to be implemented in one EFGT cycle.

13/01585 Use of rubber crumbs as drainage layer in green roofs as potential energy improvement material

Pérez, G. *et al. Applied Energy*, 2012, 97, 347–354. Today, green roofs are a building system which provides interesting benefits over traditional roof solutions. The most important advantages are the reduction of surface runoff in cities, improvement of the urban climate, biodiversity support, improvement of the durability of roofing materials, and, especially, energy savings. This paper has the aim of studying the performance of green roofs as a passive system for energy savings, within a wider objective of seeking constructive solutions suitable for sustainable and environmentally friendly architecture. This idea is tested at an experimental installation available at the University of Lleida, Spain, with several cubicles testing the energy performance of different construction solutions. This work raises the possibility of using recycled rubber from vehicle tyres as a drainage layer in green roofs, substituting the porous stone materials currently used (such as expanded clay, expanded shale, pumice, and natural puzolana). This solution would reduce the consumption of these natural materials, which also require large amounts of energy in its transformation process to obtain their properties. Moreover it would provide a solution to the problem of waste rubber from the tyres, known as rubber crumbs. Since the purpose of the drainage layer is the optimum balance between air and water in the green roof system, first the ability for draining of recycled rubber granules was studied and was compared with the offered by stone materials. The new solution using rubber crumbs is also studied to test if it would keep the same insulating properties that the green roof with stone materials presented in previous studies. Early results show that this extensive green roof system can be a good passive energy savings tool in continental Mediterranean climate in summer, and that rubber crumbs can be an interesting substitute for stone materials used as drainage layer in this type of green roofs.

emissions decrease monotonically, the soot emissions increase slightly, the hydrocarbon (HC) and carbon monoxide (CO) emissions increase, and the carbon dioxide (CO₂) and oxygen (O₂) concentration of the exhaust products increases and decreases respectively. The trade-off relationship between NO_x and soot emissions can be improved when diesel engines are fuelled with DCL instead of diesel.

13/01587 Performance optimum analysis and load matching of an energy selective electron heat engine

Su, S. *et al. Energy*, 2012, 44, (1), 570–575. A new model of the energy selective electron (ESE) heat engine with a variable bias voltage resulting from a variable load resistance is established. Analytical expressions for the power output and efficiency of the system are derived, based on the Fermi–Dirac distribution of electrons. The general performance characteristics of the system are revealed. The effects of the energy level of the central position of the filter, chemical potential, and load resistance on the performance of the system are discussed in detail. It is found that as long as the position of the filter is suitably designed, the maximum electric current may be obtained at zero load. The optimal values of two important parameters, the energy level of the central position of the filter and chemical potential or load resistance, are calculated for differently operating states, and consequently, two important criteria on the parametric optimum design are obtained. These results obtained here may provide some guidance for the optimum design of ESE heat engines.

13/01588 Single-piston alternative to Stirling engines

Glushenkov, M. *et al. Applied Energy*, 2012, 97, 743–748. Thermodynamic analysis of an unconventional heat engine was performed. The engine studied has a number of advantages compared to state-of-the-art Stirling engines. The main advantage of the engine proposed is its simplicity. A power piston is integral with a displacer and a heat regenerator. It allows solving the problem of the high-temperature sealing of the piston and the displacer typical of all types of Stirling engines. In addition the design proposed provides ideal use of the displacer volume eliminating heat losses from outside gas circuit. Both strokes of the piston are working ones in contrary to any other types of piston engines. The engine can be considered as maintenance-free as it has no piston rings or any other rubbing components requiring lubrication. The only seal is contactless and wear free. It is located in the cold part of the cylinder. As a result the leakage rate in operation can be one-two orders of magnitude as small as that in Stirling engines. Balancing of the engine is much easy compared to Stirling engines with two reciprocating masses because of the only moving part inside the engine cylinder. The engine suits ideally to be fuelled with ‘difficult’ fuels such as bio oil and can be used as a prime mover for micro-CHP systems. The thermodynamic model developed incorporates non-ideal features of the cycle, such as specific regenerator efficiency, dead volumes and other geometrical parameters of the engine. The model shows that the energy efficiency is highly sensitive to regenerator performance. For realistic geometric and operating parameters and the regenerator efficiency of about 95% the ultimate energy conversion efficiency of the engine proposed can be as high as 40–50%. A prototype of the engine was built and the feasibility of the engine concept was demonstrated.

11 ENGINES

Hybrid engine systems

Power generation and propulsion, electrical vehicles

13/01586 Experimental study on the effect of coal to liquid on combustion and emission of heavy-duty diesel engine with exhaust gas recirculation

Zhang, G. *et al. Applied Thermal Engineering*, 2012, 42, 64–70. The work aims not only to exploit the petroleum alternative fuel for relieving the energy crisis, but also to realize the ultra-low emissions of diesel engines fuelled with this alternative fuel. The effects of direct coal liquefaction (DCL) on combustion and emissions have been studied in a heavy-duty engine fuelled with exhaust gas recirculation (EGR). Two cases of the diesel engine operating condition were studied: 1000 revs/min, 110 N m (referred to as Case A) and 1400 revs/min, 473 N m (referred to as Case B). The experimental results showed that with the increase of EGR, the maximum in-cylinder pressure, rate of heat release and mean gas temperature decrease; the brake fuel conversion efficiency (BFCE) first increases slightly then decreases; brake specific fuel consumption (BSFC) has the opposite variation trend to BFCE. As the increase of EGR, the nitrogen oxides (NO_x)

13/01589 A comparison of performance of higher alcohols/diesel fuel blends in a diesel engine

Campos-Fernández, J. *et al. Applied Energy*, 2012, 95, 267–275. The use of alcohols provides an attractive alternative fuel for internal combustion engines. Moreover, alcohol can be produced by biorefineries, thus reducing the consumption of fossil resources. Up until now, research related to the use of alcohols as alternative fuels for internal combustion engines has been focused on the employment of short chain alcohols, mainly methanol and ethanol, blended with fossil fuels. Despite their adequate combustion properties, long chain alcohols like butanol or pentanol have been barely investigated. The objective of this work was to compare the short-term performance of a direct injection diesel engine fuelled with different 1-butanol/diesel and 1-pentanol/diesel fuel blends, without any modifications of the engine. To gain knowledge about the implications of the use of the proposed blends, results were compared with those achieved with the use of neat diesel fuel. 1-Butanol/diesel fuel blends (from 10% to 30% of 1-butanol by volume) and 1-pentanol/diesel fuel blends (from 10% to 25% of 1-pentanol by volume) were tested. Experimental results showed a slight engine power loss and an increase in brake thermal efficiency when the engine was fuelled with higher alcohols blends instead of straight diesel fuel. However, some 1-butanol blends

depicted a decrease in the brake specific fuel consumption compared to the use of neat diesel fuel. After using 1-butanol blends and 1-pentanol blends, no engine performance problems were visually detected. Moreover, statistical analysis showed no significant differences between tests. It can be concluded from this field trial that a diesel engine, without any modifications, can run successfully on a blend up to 30% 1-butanol/70% diesel fuel or 25% 1-pentanol/75% diesel fuel without externally apparent damage to the engine parts. Nevertheless, to recommend its use as a substitute of straight diesel fuel, long-term durability tests are needed.

13/01590 Combustion and emission of rapeseed oil blends in diesel engine

Labecki, L. *et al. Applied Energy*, 2012, 95, 139–146.

Combustion and emission characteristics of rapeseed plant oil (RSO) and its blends with diesel fuel have been investigated in a multi-cylinder direct injection diesel engine. Plant oils have high viscosities compared to diesel and this affects the performance and durability of automotive diesel engines when used for longer time periods. Despite these adverse effects the exhaust emissions analysis show a significant reduction in NO_x and relatively higher amount of soot for RSO compared to diesel fuel. An attempt has been made to reduce soot emissions from the combustion of RSO to exploit the advantage of its low NO_x emissions. The strategy of varying injection parameters such as injection pressures and injection timings have been used in this work to reduce the soot emissions for blends of 50% and 30% RSO in diesel fuel. Using this strategy it was possible to achieve diesel equivalent levels of soot emission for 30% RSO blend. Under diesel equivalent soot emission levels, it was also possible to achieve a further reduction in NO_x emissions by up to 22% for 30% RSO blend, this was achieved at the expense of THC, CO and BSFC. The exhaust soot particle number concentrations for 30% RSO blend reduces with an increase in injection pressure and retarded injection timing. However, when compared to diesel, the exhaust soot particle number concentration for 30% RSO blend was still higher, even after diesel equivalent level of soot emission was achieved.

13/01591 Effects of oxygen enriched air on the operation and performance of a diesel-biogas dual fuel engine

Cacua, K. *et al. Biomass and Bioenergy*, 2012, 45, 159–167.

The effect of oxygen-enriched air was tested for a diesel-biogas dual fuel engine. The operation and performance characteristics, such as thermal efficiency, pollutant emissions and combustion parameters were determined. Experiments have been carried out with a stationary compression ignition (CI) engine coupled with a generator in dual mode using a typical biogas composition of 60 vol.% CH_4 and 40 vol.% CO_2 . For every engine load evaluated, the oxygen concentration in the intake air engine was varied from 21% to 27% O_2 v/v. Ignition delay time and methane emissions were decreased when using oxygen enriched air with respect to normal air (21% O_2), whereas the thermal efficiency was increased.

13/01592 Investigation on combustion characteristics and emissions of diesel/hydrogen mixtures by using energy-share method in a diesel engine

Wu, H.-W. and Wu, Z.-Y. *Applied Thermal Engineering*, 2012, 42, 154–162.

Considering hydrogen as a clean alternative fuel for engines, this paper is to develop a procedure to add hydrogen in an intake manifold and to design an exhaust gas recirculation (EGR) system for a direct injection diesel engine. The cylinder gas pressure, air mass flow, fuel mass flow, and emissions (such as CO , CO_2 , HC, NO_x , and smoke) were measured under various engine loads and 0%–40% EGR ratios adjusting the hydrogen-energy-share ratio at 0–20%, meaning that the energy of hydrogen replaced 0–20% that of diesel fuel. The combustion characteristics such as cyclic variations, heat release rate, brake thermal efficiency, and specific fuel consumption were determined. The results show that the variation coefficient values of indicated mean effective pressure are from 0.9% to 2.8%. The rate of decrease in the smoke emission is 37.6%, and that in the NO_x emission is 59.5% for a 60% load, 40% EGR ratio, and 20% added hydrogen.

Transport battery development

13/01593 A new comparison between the life cycle greenhouse gas emissions of battery electric vehicles and internal combustion vehicles

Ma, H. *et al. Energy Policy*, 2012, 44, 160–173.

Electric vehicles have recently been gaining increasing worldwide interest as a promising potential long-term solution to sustainable personal mobility; in particular, battery electric vehicles (BEVs) offer zero tailpipe emissions. However, their true ability to contribute to greenhouse gas (GHG) emissions reductions can only be properly assessed by comparing a life cycle assessment of their GHG emissions with a similar assessment for conventional internal combustion vehicles (ICVs). This paper presents an analysis for vehicles typically expected to be introduced in 2015 in two example markets (the UK and California, USA), taking into account the impact of three important factors: (1) like-for-like vehicle comparison and effect of real-world driving conditions; (2) accounting for the GHG emissions associated with meeting the additional electricity demand for charging the batteries and (3) GHG emissions associated with vehicle manufacture, disposal, etc. This work demonstrates that all of these factors are important and emphasizes that it is therefore crucial to clearly define the context when presenting conclusions about the relative GHG performance of BEVs and ICVs – such relative performance depends on a wide range of factors, including the marginal regional grid GHG intensity, vehicle size, driving pattern, loading, etc.

13/01594 Analysis and implementation of an adaptive PV based battery floating charger

Karami, N. *et al. Solar Energy*, 2012, 86, (9), 2383–2396.

In a system composed of a photovoltaic (PV) cell, a converter and a resistive load, the maximum power point tracking techniques are applied at the output of the PV panel and not at the level of the load. In this study, the considered load is a battery at different states of charge (SOC) that is charged by the PV panel. The power consumed by the battery is related to its SOC. Consequently, an empty battery consumes more current than a charged one. At full state of charge, the battery does not call for more energy and thus it is not rewarding to extract more power from the PV panel. Besides, in a stand-alone photovoltaic system, the size of the PV panel and the battery should be respected. Thus, the PV current at different irradiances should be compatible with the charging current required to charge the battery at different SOC. A critical situation occurs at high irradiance when the PV panel delivers a high current at maximum power point (MPP) that exceeds the tolerated charging current. The current reaches the top limit when the battery is totally empty, caused by the big difference in potential between the converter output and the battery voltages. In this case, the battery starts to gas when attempts are made to charge it faster than it can absorb the energy. On the other hand, in a fully charged battery, the difference in potential between the converter and the battery is zero. In this case, there is no need to track the MPP. Here, the authors will focus on the load type and suggest new methods to reach the MPP depending on the load state. In the proposed designs, the components of the stand-alone system are protected even if they are not well sized. In addition, the authors will focus on the development of the PV array mathematical model. The results achieved with the system, as well as the experimental results of a laboratory prototype, will be given.

13/01595 Behavior and state-of-health monitoring of Li-ion batteries using impedance spectroscopy and recurrent neural networks

Eddahech, A. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 487–494.

Research into the monitoring of lithium-ion batteries has become increasingly important, due to their use in a variety of complex, high-performance, energy-storage applications in hybrid and electric vehicles (HEV and EV). This paper investigates the behaviour and state-of-health monitoring of lithium-ion batteries. The first part presents a model for a high-energy-density lithium-ion cell dedicated to EV applications, based on electrochemical impedance spectroscopy measurements. The key characteristic of this model, based on an equivalent-circuit approach, is not only its simplicity, but also the fact it takes into account several important phenomena that occur inside lithium cells, such as the dependence of part of the internal resistance and the open-circuit voltage on the state of charge. The second part describes state-of-health monitoring of a high-power-density lithium-ion cell, using recurrent neural networks to predict the deterioration in battery performance. This comprehensive approach was used to monitor several batteries dedicated to HEV and EV applications, covering the entire process, from behaviour modelling to predicting performance degradation and use.

13/01596 Damping performance analysis of battery energy storage system, ultracapacitor and shunt capacitor with large-scale photovoltaic plants

Shah, R. *et al. Applied Energy*, 2012, 96, 235–244.

As large-scale photovoltaic (PV) generation reaches higher penetration levels, there is a greater need to meet the certain grid code requirements for interconnection. Ultracapacitor, battery energy storage system (BESS) or shunt capacitor have recently been used as

auxiliary devices for large-scale PV generator system to meet the grid code requirements for interconnection. Although the individual auxiliary devices are well documented, a comparative study of these devices impact on the damping of electromechanical (EM) modes and oscillatory instability problem has not been reported so far. This paper aims to fill in the gap, and provides a comparative analysis of these auxiliary devices performance along with PV plant on the damping of EM modes. The oscillation problem is analysed by considering different types of synchronous generator (e.g. hydro, thermal) as the non-electrical components of hydro and thermal units have major influences on system dynamics. The comparisons are based on the results obtained from two-area test system and New England-New York test system (16-machine, 68-bus system), which are the benchmark systems for angular stability analysis.

13/01597 Designing lead-acid batteries to meet energy and power requirements of future automobiles

Moseley, P. T. *et al. Journal of Power Sources*, 2012, 219, 75–79.
A review is given of the factors that mitigate against the successful use of lead-acid batteries in the high-rate partial-state-of-charge duties experienced in hybrid electric vehicles, together with a consideration of successful remedies for those factors. Fuel cell, plug-in hybrid electric and battery electric vehicles have all appeared initially to offer promise but, upon closer scrutiny, each retains some challenge in terms of cost and/or uncertain life-cycle emissions penalties. Nevertheless, strong interest continues in the commercial realization of proven, low-cost, technologies for sustainable road transport. Simple modifications to traditional designs of the lead-acid battery enable a low-cost route to the achievement of the necessary improvements in vehicle performance.

13/01598 Dynamic modeling and analysis of a pouch type LiMn_2O_4 /Carbon high power Li-polymer battery based on electrochemical-thermal principles

Xiao, M. and Choe, S.-Y. *Journal of Power Sources*, 2012, 218, 357–367.

A dynamic model for a pouch type Li-polymer battery based on electrochemical and thermal principles is developed to analyse static and dynamic performances of a single cell. The model for the single cell is a quasi-three-dimensional, constructed by connecting one-dimensional models for micro cells using current collectors. The developed model can represent distributions of temperature, potentials, and current flows along with distribution of lithium ions through the plane. The model is coded using MATLAB and validated against a LiMn_2O_4 /carbon pouch type power cell. The static analysis includes responses of the terminal voltage at different current rates derived from the distribution of overpotentials in the micro cell as function of state of charge as well as distribution of potentials and current flows in the single cell. Ion concentration in the electrodes and electrolyte of the micro cell are analysed. The dynamic analysis includes voltage and temperature responses during charging and discharging processes. The results demonstrate effects of operation conditions on key variables of the cell performance that includes distribution of ions in the electrodes and electrolyte in micro cells as well as distribution of heat generation in single cell level during a charging and discharging process.

13/01599 Electronic integration of fuel cell and battery system in novel hybrid vehicle

Fisher, P. *et al. Journal of Power Sources*, 2012, 220, 114–121.
The objective of this work was to integrate a lithium ion battery pack, together with its management system, into a hydrogen fuel cell drive train contained in a lightweight city car. Electronic units were designed to link the drive train components using conventional circuitry. These were built, tested and shown to perform according to the design. These circuits allowed start-up of battery management system, motor controller, fuel cell warm-up and torque monitoring. After assembling the fuel cell and battery in the vehicle, full system tests were performed. Analysis of results from vehicle demonstrations showed operation was satisfactory. The conclusion was that the electronic integration was successful, but the design needed optimization and fine tuning. Eight vehicles were then fitted with the electronically integrated fuel cell-battery power pack. Trials were then started to test the integration more fully, with a duration of 12 months from 2011 to 2012 in the CABLED project.

13/01600 Energy management strategy for fuel cell/battery/ultracapacitor hybrid vehicle based on fuzzy logic

Li, Q. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 514–525.

In order to enhance the fuel economy of hybrid vehicle and increase the mileage of continuation of journey, a fuzzy logic control is utilized to design energy management strategies for fuel cell/battery (FC + B) hybrid vehicle and fuel cell/battery/ultra-capacitor (FC + B + UC) hybrid vehicle. The models of hybrid vehicle for FC + B and FC + B + UC structure are developed by electric vehicle simulation

software ADVISOR which uses a hybrid backward/forward approach. The results demonstrate that the proposed control strategy can satisfy the power requirement for four standard driving cycles and achieve the power distribution among various power sources. The comprehensive comparisons with the power tracking control strategy which is wide adopted in ADVISOR verify that the proposed control strategy has better rationality and validity in terms of fuel economy and dynamic property in four standard driving cycles. Therefore, the proposed strategy will provide a novel approach for the advanced energy management system of hybrid vehicle.

13/01601 Impact of vehicle-to-grid on power system operation costs: the Spanish case study

Fernandes, C. *et al. Applied Energy*, 2012, 96, 194–202.

Climate change, added to security of supply concerns, has been leading many countries to strongly support the development of electric vehicles (EVs) not only as a cleaner and more energy efficient source of transportation but also as a flexible electricity storage option. However, the massive deployment of EVs will impose important challenges to power systems operation. In this context, this paper investigates the impact of EVs with vehicle-to-grid capability to power system operation. Since this impact depends on the power system considered and on the number (and type) of EVs, different scenarios for renewable energy sources (RES) generation and EV penetration are studied. A detailed analysis of the impact of EVs the Spanish power system – demand, generation, use of flexible units (pumped storage) and power reserve, and energy curtailment – is performed. For this purpose, a mid-term operation model that computes generation dispatch and simulates hourly power system operation is used. The advantage of this model is that it includes EVs in the unit commitment and represents in detail mobility and connection patterns, which allows the estimation of more realistic results.

13/01602 Influence of plug-in hybrid electric vehicle charging strategies on charging and battery degradation costs

Lunz, B. *et al. Energy Policy*, 2012, 46, 511–519.

The profitability of plug-in hybrid electric vehicles (PHEVs) is significantly influenced by battery aging and electricity costs. Therefore, a simulation model for PHEVs in the distribution grid is presented which allows one to compare the influence of different charging strategies on these costs. The simulation is based on real-world driving behaviour and European Energy Exchange (EEX) intraday prices for obtaining representative results. The analysis of comprehensive lithium-ion battery aging tests performed within this study shows that especially high battery states of charge (SOCs) decrease battery lifetime, whereas the cycling of batteries at medium SOCs only has a minor contribution to aging. Charging strategies that take into account the previously mentioned effects are introduced, and the SOC distributions and cycle loads of the vehicle battery are investigated. It can be shown that appropriate charging strategies significantly increase battery lifetime and reduce charging costs at the same time. Possible savings due to lifetime extension of the vehicle battery are approximately two times higher than revenues due to energy trading. The findings of this work indicate that car manufacturers and energy/mobility providers have to make efforts for developing intelligent charging strategies to reduce mobility costs and thus foster the introduction of electric mobility.

13/01603 Market penetration speed and effects on CO₂ reduction of electric vehicles and plug-in hybrid electric vehicles in Japan

Yabe, K. *et al. Energy Policy*, 2012, 45, 529–540.

In order to reduce CO₂ emissions in the passenger vehicle sector, mass introduction of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) is required despite their high battery costs. This paper forecasts the rate at which EV/PHEV will penetrate into the market in the future and the effects of that spread on CO₂ reduction by using a learning curve for lithium-ion batteries, distribution of daily travel distance for each vehicle, and an optimal power generation planning model for charging vehicles. Taking into consideration each driver's economical viewpoint, the speed at which the EV/PHEV share of the new passenger vehicle market grows is fairly slow. The optimum calculation in the base case shows that the share of EV/PHEV is only a quarter even in 2050. However, the initial price and progress rate of batteries have a great effect on this share. Therefore, long-term economic support from the government and significant R&D innovation are required to reduce CO₂ drastically through cutting down battery price. The results also show how much the CO₂ emission intensity of power generation affects the CO₂ reduction rate by introducing EV/PHEV.

13/01604 Microporous separators for Fe/V redox flow batteries

Wei, X. *et al. Journal of Power Sources*, 2012, 218, 39–45.

The Fe/V redox flow battery has demonstrated promising performance with distinct advantages over other redox flow battery systems. Due to the less oxidative nature of the Fe(III) species, hydrocarbon-based ion exchange membranes or separators can be used. Daramic[®] microporous polyethylene separators were tested on Fe/V flow cells using sulfuric/chloric mixed acid-supporting electrolytes. Among them, separator C exhibited good flow cell cycling performance with satisfactory repeatability over a broad temperature range of 5–50 °C. Energy efficiency (EE) of C remains around 70% at current densities of 50–80 mA cm⁻² in temperatures ranging from room temperature to 50 °C. The capacity decay problem could be circumvented through hydraulic pressure balancing by means of applying different pump rates to the positive and negative electrolytes. Stable capacity and energy were obtained over 20 cycles at room temperature and 40 °C. These results show that extremely low-cost separators (\$1–20 m⁻²) are applicable in the Fe/V flow battery system with acceptable energy efficiency. This represents a remarkable breakthrough: a significant reduction of the capital cost of the Fe/V flow battery system, which could further its market penetration in grid stabilization and renewable integration.

13/01605 Model-based dynamic multi-parameter method for peak power estimation of lithium-ion batteries

Sun, F. *et al. Applied Energy*, 2012, 96, 378–386.

A model-based dynamic multi-parameter method for peak power estimation is proposed for batteries and battery management systems (BMSs) used in hybrid electric vehicles (HEVs). The available power must be accurately calculated in order to not damage the battery by overcharging or overdischarging or by exceeding the designed current or power limit. A model-based dynamic multi-parameter method for peak power estimation of lithium-ion batteries is proposed to calculate the reliable available power in real time, and the design limits such as cell voltage, cell current, cell SOC, cell power are all used as its constraints; more importantly, the relaxation effect also is considered. Where, to improve the model's accuracy, the ohmic resistance of the Thevenin model for the lithium-ion battery has been refined; in order to further improve the polarization parameters identification precision, a genetic algorithm has been used to gain the optimal time constant. Lastly, a test with several consecutive Federal Urban Driving Schedules profiles is carried to evaluate the model-based dynamic multi-parameter method for peak power estimation. The experimental and simulation results indicate that the model-based dynamic multi-parameter method for peak power estimation can calculate the terminal voltage and the current available power much more reliably and accurately.

13/01606 Online cell SOC estimation of Li-ion battery packs using a dual time-scale Kalman filtering for EV applications

Dai, H. *et al. Applied Energy*, 2012, 95, 227–237.

For the vehicular operation, due to the voltage and power/energy requirements, the battery systems are usually composed of up to hundreds of cells connected in series or parallel. To accommodate the operation conditions, the battery management system (BMS) should estimate state of charge (SOC) to facilitate safe and efficient utilization of the battery. The performance difference among the cells makes a pure pack SOC estimation hardly provide sufficient information, which at last affects the computation of available energy and power and the safety of the battery system. So for a reliable and accurate management, the BMS should 'know' the SOC of each individual cell. Several possible solutions on this issue have been reported in the recent years. This paper studies a method to determine online all individual cell SOC of a series-connected battery pack. This method, with an equivalent circuit based 'averaged cell' model, estimates the battery pack's average SOC first, and then incorporates the performance divergences between the 'averaged cell' and each individual cell to generate the SOC estimations for all cells. This method is developed based on extended Kalman filter, and to reduce the computation cost, a dual time-scale implementation is designed. The method is validated using results obtained from the measurements of a Li-ion battery pack under three different tests, and analysis indicates the good performance of the algorithm.

13/01607 Optimisation of a photovoltaic battery ultracapacitor hybrid energy storage system

Glavin, M. E. and Hurley, W. G. *Solar Energy*, 2012, 86, (10), 3009–3020.

Autonomous photovoltaic panels are intermittent sustainable energy sources which require energy storage to balance generation and demand, as photovoltaic generation is time and weather dependent. Traditionally batteries are the most common storage technology for photovoltaic systems. Photovoltaic batteries can encounter extended periods of low state of charge (SOC), resulting in sulfation and stratification, reducing battery lifetime. Standalone photovoltaic systems are often used in remote areas away from the national grid for water irrigation system, requiring DC motor starting resulting in

high inrush current, cathodic protection systems for oil and gas pipelines, emergency phones, warning signs, and telecommunication repeater stations, resulting in pulse discharging of the battery. A combination of depleted battery SOC and high burst current can result in premature loss of load due to stringent battery low voltage disconnect (LVD) limits implemented by the battery management system. A combination of valve regulated lead acid (VRLA) batteries and ultracapacitors in a hybrid energy storage system (HESS), which increases the power density of the overall system, is examined. Operating the ultracapacitor bank under high power conditions reduces the strain of large current extraction from the battery bank. The addition of the ultracapacitor bank presents the need for a methodology to optimize the photovoltaic system to prevent excess battery storage. This paper outlines the methodology utilized to optimize the combination of photovoltaic panels, batteries, and ultracapacitors for a given solar radiation and load profile employing Matlab software.

13/01608 Optimization of a PEMFC/battery pack power system for a bus application

Barelli, L. *et al. Applied Energy*, 2012, 97, 777–784.

In a global environment context in which the urgent need to reduce pollutant emissions is of central relevance, it is becoming increasingly important the research for solutions, concerning the vehicular transport sector with low environmental impact. Fuel cell technology is expected to become a viable solution for these applications due to its environmental friendly characteristics. The present study concerns the traction system of a bus considering the case of hybrid solutions consisting of a proton exchange membrane fuel cell (PEMFC) in parallel with a battery pack. In particular, a dynamic model of a PEMFC/battery system is presented for the application under study. The model incorporates the dynamics of the fuel cell and the state of charge (SOC) of the battery pack. The fuel cell and the battery output power have been determined according to the real driving load demand of a bus taking into consideration a daily operation of 12 h. Such a model has allowed the correct dimensioning of the hybrid power system (giving a particular attention to the fuel cell and the hydrogen tank) together with the optimization of the SOC control strategy.

13/01609 Predicting the market potential of plug-in electric vehicles using multiday GPS data

Khan, M. and Kockelman, K. M. *Energy Policy*, 2012, 46, 225–233.

GPS data for a year's worth of travel by 255 Seattle households illuminate how plug-in electric vehicles can match household needs. The results suggest that a battery-electric vehicle (BEV) with 100 mi of range should meet the needs of 50% of one-vehicle households and 80% of multiple-vehicle households, when charging once a day and relying on another vehicle or mode just 4 days a year. Moreover, the average one-vehicle Seattle household uses each vehicle 23 miles per day and should be able to electrify close to 80% of its miles, while meeting all its travel needs, using a plug-in hybrid electric vehicle (PHEV) with 40-mile all-electric range. Households owning two or more vehicles can electrify 50–70% of their total household miles using a PHEV40, depending on how they assign the vehicle across drivers each day. Cost comparisons between the average single-vehicle household owning a Chevrolet Cruze versus a Volt PHEV suggest that, when gas prices are \$3.50 per gallon and electricity rates are at 11.2¢/kWh, the Volt will save the household \$535 per year in operating costs. Similarly, the Toyota Prius PHEV will provide an annual savings of \$538 per year over the Corolla.

13/01610 Proton exchange membrane fuel cells cold startup global strategy for fuel cell plug-in hybrid electric vehicle

Henao, N. *et al. Journal of Power Sources*, 2012, 220, 31–41.

This paper investigates the proton exchange membrane fuel cell (PEMFC) cold startup problem within the specific context of the plug-in hybrid electric vehicles (PHEV). A global strategy which aims at providing an efficient method to minimize the energy consumption during the startup of a PEMFC is proposed. The overall control system is based on a supervisory architecture in which the energy management system (EMS) plays the role of the power flow supervisor. The EMS estimates in advance, the time to start the fuel cell (FC) based upon the battery energy usage during the trip. Given this estimation and the amount of additional energy required, the fuel cell temperature management strategy computes the most appropriate time to start heating the stack in order to reduce heat loss through the natural convection. As the cell temperature rises, the PEMFC is started and the reaction heat is used as a self-heating power source to further increase the stack temperature. A time optimal self-heating approach based on the Pontryagin minimum principle is proposed and tested. The experimental results have shown that the proposed approach is efficient and can be implemented in real-time on FC-PHEVs.

13/01611 Recent advances in the development of Li–air batteries

Capsoni, D. *et al. Journal of Power Sources*, 2012, 220, 253–263.
The global energy demand calls for more efficient storage systems. In this review, the state of the art of Li/air and Li/O₂ batteries is discussed with particular attention on the more recent findings regarding all the battery compartments. Both aqueous and non-aqueous systems are considered, and the most critical issues for better battery design are addressed. Whereas the predicted charge/discharge values for these devices do justify the intense research efforts performed nowadays, great problems are still present which must be overcome in order to make Li/air and Li/O₂ a reality for future large-scale applications.

13/01612 Research on energy management of dual energy storage system based on the simulation of urban driving schedules

Pan, C. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 37–42.

This work presents the modelling and simulation of a dual energy storage system and the corresponding energy management system. The dual energy storage system composed of battery and ultra-capacitor displays desirable performance for vehicle propulsion. As the ultra-capacitor can fulfil the instantaneous power demand fluctuations, the battery can fit the average power demand without facing peak loads. The energy management system can meet the power demand of a vehicle in a suitable way in order to maximize the power performance while facilitating the fuel economy and lifetime of the energy storage system components. The simulation results of the electric vehicle speed matched the speed curve of the urban driving schedules, the inverter DC side currents can meet the power demands under the urban driving schedules, indicating that the dual energy storage system consisting of battery and ultra-capacitor can meet the vehicle power demands. Also, the battery nearly stayed in low-current discharge state, therefore the energy management system can fulfil the power performance of the electric vehicle, meanwhile the battery can remain in the best working conditions. When the vehicle braked, the energy store in the ultra-capacitor was significantly increased, indicating that the utilization rate of the energy was improved by the energy management system, thus the endurance mileage of electric vehicle was prolonged. Consequently, compared to the energy storage system of battery alone, the dual energy storage system composed of battery and ultra-capacitor has obvious advantages of high power density and high energy density under the control of the energy management technology.

13/01613 Robust controller design of microturbine and electrolyzer for frequency stabilization in a microgrid system with plug-in hybrid electric vehicles

Vachirasricirikul, S. and Ngamroo, I. *International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 804–811.

This paper proposes a new robust controller design of microturbine (MT) and electrolyser (ES) in a control and monitoring system (CMS) for frequency stabilization in a microgrid system with plug-in hybrid electric vehicles (PHEVs). In the studied microgrid, the MT is normally used to provide the main power to the loads while the ES absorbs the power from the system to produce the hydrogen as the fuel input for the power generation of the fuel cell. On the other hand, the large numbers of PHEVs are utilized in the consumer side. The concurrent charging powers of PHEVs cause a problem of severe frequency fluctuation in the microgrid. To solve this problem, the frequency stabilization of CMS is performed by controlling the power output of MT and ES. The controller structure of MT and ES is a proportional integral with a single input. To enhance the tracking performance and the robustness against system uncertainties of the designed MT and ES controllers, the control parameters are optimized by shuffled frog leaping algorithm based on specified-structure mixed H_2/H_∞ control technique. Simulation results not only show the frequency stabilization effect against the random charging power of PHEVs but also the high robustness of the proposed robust MT and ES controllers against the system parameters variation.

13/01614 The importance of ‘going nano’ for high power battery materials

Bresser, D. *et al. Journal of Power Sources*, 2012, 219, 217–222.
The electrochemical performance of spinel Li₄Ti₅O₁₂ (LTO) nanoparticles synthesized by flame spray pyrolysis with an average diameter of approximately 20–30 nm is reported in this manuscript and compared with that of micro-sized LTO particles (1–2 µm) formed by a thermal post-treatment of the nanoparticles. The significantly advanced high rate capability of nano-sized LTO is evidenced by the results from the galvanostatic tests with applied current densities of up to 17.5 Ag^{−1}, corresponding to a full (dis-)charge of the cell within less than 40 s. For nano-sized LTO, specific capacities of 115 and 70 mAhg^{−1} were obtained for applied rates of 10 C and 100 C, respectively, thus confirming the essential influence of particle size of lithium titanate on its high rate capability and practical power density. Moreover, a

capacity retention of around 94.8% was observed after 1000 cycles at 10 C, presenting LTO nanoparticles synthesized by FSP as highly promising anode material for high power lithium-ion battery applications.

13/01615 Thermal battery with CO₂ compression heat pump: techno-economic optimization of a high-efficiency Smart Grid option for buildings

Blarke, M. B. *et al. Energy and Buildings*, 2012, 50, 128–138.

Increasing penetration levels of wind and solar power in the energy system call for the development of smart grid enabling technologies. As an alternative to expensive electrochemical and mechanical storage options, the thermal energy demand in buildings offers a cost-effective option for intermittency-friendly electricity consumption patterns. Combining hot and cold thermal storages with new high-pressure compressor technology that allows for flexible and simultaneous production of useful heat and cooling, the paper introduces and investigates the high-efficiency thermal battery (TB) concept. In a proof-of-concept case study, the TB replaces an existing electric resistance heater used for hot water production and an electric compressor used for air refrigeration in a central air conditioning system. A mathematical model for least-cost unit dispatch is developed. Heat pump cycle components and thermal storages are designed and optimized. A general methodology is applied that allows for comparing the obtained results with other smart grid enabling options. It is found that the TB concept leads to improvements in the intermittency-friendliness of operation R_c (improves from −0.11 to 0.46), lower CO₂ emissions (reduced to zero), and lower operational costs (reduced by 72%). The results indicate that TB may be the most cost-effective Smart Grid enabling option for supporting higher penetration levels of intermittent renewables in the energy system.

13/01616 Thermodynamic analyses of solar thermal gasification of coal for hybrid solar-fossil power and fuel production

Ng, Y. C. and Lipiński, W. *Energy*, 2012, 44, (1), 720–731.

Thermodynamic analyses are performed for solar thermal steam and dry gasification of coal. The selected types of coal are anthracite, bituminous, lignite and peat. Two model conversion paths are considered for each combination of the gasifying agent and the coal type: production of the synthesis gas with its subsequent use in a combined cycle power plant to generate power, and production of the synthesis gas with its subsequent use to produce gasoline via the Fischer–Tropsch synthesis. Replacement of a coal-fired 35% efficient Rankine cycle power plant and a combustion-based integrated gasification combined cycle power plant by a solar-based integrated gasification combined cycle power plant leads to the reduction in specific carbon dioxide emissions by at least 47% and 27%, respectively. Replacement of a conventional gasoline production process via coal gasification and a subsequent Fischer–Tropsch synthesis with gasoline production via solar thermal coal gasification with a subsequent Fischer–Tropsch synthesis leads to the reduction in specific carbon dioxide emissions by at least 39%.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

13/01617 A mechanistic-based healing model for self-healing glass seals used in solid oxide fuel cells

Xu, W. *et al. Journal of Power Sources*, 2012, 218, 445–454.

The use of self-healing glass as hermetic seals is a recent advancement in sealing technology development for the planar solid oxide fuel cells (SOFCs). Because of its capability to restore mechanical properties at elevated temperatures, the self-healing glass seal is expected to provide high reliability in maintaining the long-term structural integrity and functionality of SOFCs. To accommodate the design and evaluate the effectiveness of these engineered seals under various thermomechanical operating conditions, a computational modelling framework must be developed to accurately capture and predict the healing behaviour of the glass material. In the present work, a mechanistic-based, two-stage model was developed to study the stress and temperature-dependent crack healing of the self-healing glass materials. The model initially was first calibrated by experimental measurements combined with kinetic Monte Carlo (kMC) simulation results and then

implemented into finite element analysis (FEA). The effects of various factors, e.g. stress, temperature, and crack morphology, on the healing behaviour of the glass were investigated and discussed.

13/01618 Exergoeconomic analysis of glazed hybrid photovoltaic thermal module air collector

Agrawal, S. and Tiwari, G. N. *Solar Energy*, 2012, 86, (9), 2826–2838. In this paper, an exergoeconomic analysis has been carried out and on the basis of this analysis it has been concluded that in terms of energy saving the glazed hybrid photovoltaic thermal (PVT) module air collector offers a greater potential compared to PV module. The experimental validation for glazed hybrid PVT module air collector has also been performed and it has been observed that there is a good agreement between the theoretical and experimental values with correlation coefficient in range of 0.96–0.99 and root mean square percentage deviation in range of 2.38–7.46. The experiments have been carried out on clear days during the month July 2010 to June 2011. For the validation of theoretical results with experimental results, a typical day of winter month (8 December 2010) and summer month (11 April 2011) has been considered. An experimental uncertainty for December and April months is 11.6% and 2.1%, respectively. The annual overall thermal energy and exergy gain are 1252.0 and 289.5 kWh, respectively. The annual net electrical energy savings by glazed hybrid PVT module air collector is 234.7 kWh.

13/01619 Experimental performance evaluation of aerogel glazing systems

Buratti, C. and Moretti, E. *Applied Energy*, 2012, 97, 430–437. Energy savings for heating, air conditioning and illuminating plants could be improved by innovative transparent insulation materials (TIMs), which aim to optimize two opposite requirements: transparency and thermal insulation. Aerogel is one of the most promising materials for use in highly energy-efficient windows: in addition to the low thermal conductivity (down to 0.010 W/(mK) in evacuated conditions), a high solar energy and daylight transmittance is achieved. Eight samples were manufactured, by assembling several types of glass with monolithic and granular aerogel in the interspace. U -values slightly higher than 1 W/m²K were obtained for all the samples. The monolithic aerogel introduced a better light transmittance ($\tau_v = 0.60$) than granular one ($\tau_v = 0.27$), while U -values were comparable in non-evacuated conditions. With respect to a conventional window (double glazing with a low-e layer), 55% reduction in heat losses was achieved by monolithic aerogel, with only a 25% reduction in light transmittance; for the granular systems, the reduction was about 25% in heat losses, but 66% in light transmission. In order to evaluate the aerogel employing in buildings, a prototype of an aluminium frame window with granular aerogel in interspace was realized. Thermal and acoustic properties of the prototype were evaluated according to the standards. The thermal transmittance of the innovative glazing system was little lower than 1 W/(m²K) and it showed also good acoustic properties: the R_w index was 3 dB higher than the one of a conventional window with air in interspace.

13/01620 Glass–film-combination: opto-physical properties and energy saving potential of a novel greenhouse glazing system

Max, J. F. J. et al. *Energy and Buildings*, 2012, 50, 298–307. A combination of anti-reflection coated glass and ethylene tetrafluoroethylene film is introduced as a novel glazing system for greenhouses and similar buildings. It combines the advantages of the individual materials (durability/low weight; favourable condensation behaviour/self-cleaning) and of single and double-layer systems (light transmission/insulation). By inflating/deflating the glass–film interspace, the additional insulation can be switched on and off. Since no standard method for this purpose is available, a hot box-system was developed to measure heat transfer coefficients (U -values) of different models of the glass–film-combination (GFC) and other commonly used greenhouse glazing materials at different surface inclinations; with or without condensation. Surface inclination did not greatly influence heat transfer. Condensation increased the U -values more pronounced for single layer-systems than for the GFC. Influences of wind velocity on heat transfer decreased with the degree of insulation. Overall, when mounted with adhesive tape, the energy efficiency of the GFC was 38% higher compared to customary float glass. The energy saving potential of plastic profile mounted GFC versions was 50% and 64% for the double and triple layer system (ETFE-film on both sides of the glass pane), respectively. PAR transmission of the GFC was similar to single pane float glass, its ultraviolet transmittance markedly higher.

13/01621 Impact of window selection on the energy performance of residential buildings in South Korea

Ihm, P. et al. *Energy Policy*, 2012, 44, 1–9. With rapidly increasing energy consumption attributed to residential buildings in South Korea, there is a need to update requirements of the building energy code in order to improve the energy performance of

buildings. This paper provides some guidelines to improve the building energy code to better select glazing types that minimize total energy use of residential buildings in Korea. In particular, detailed energy simulation analyses coupled with economic and environmental assessments are carried out to assess the thermal, economical, and environmental impacts of glazing thermal characteristics as well as window sizes associated with housing units in various representative climates within South Korea. The results of the analyses have clearly indicated that selecting glazing with low solar heat gain coefficient is highly beneficial especially for large windows and for mild climates. In particular, it is found that using any double-pane low-e glazing would provide better performance for windows in residential buildings than the clear double-pane glazing, currently required by the Korean building energy code.

13/01622 *In situ* and laboratory investigation of the alteration of Boom clay (Oligocene) at the air–geological barrier interface within the Mol underground facility (Belgium): consequences on kerogen and bitumen compositions

Blanchart, P. et al. *Applied Geochemistry*, 2012, 27, (12), 2476–2485. The Boom clay formation (Oligocene) is studied as a reference host rock for methodological studies on deep geological disposal of radioactive waste. During excavation of galleries within the clay formation (HADES underground research facility, Mol, Belgium), the physicochemical conditions are significantly modified as an air–clay interface is created. In order to study the long-term impact of the air–clay contact on the organic matter contained in the boom clay, two types of samples were studied: (1) a reference series of clay samples having been in contact with the atmosphere of the HADES gallery for increasing times up to several years and (2) unaltered clay samples submitted to artificial oxidation in a ventilated oven at 80 °C. The evolution of geochemical data of the two series was compared using Rock-Eval pyrolysis, GC–MS and size exclusion chromatography. The organic matter of the unaltered clays sampled in the HADES galleries is dominated by type III kerogen (terrestrial) with some contribution of type II (marine) and is thermally immature. The evolution of geochemical parameters during air alteration for the two series are very similar. They show progressive oxidation of kerogen accompanied by the release of bitumen enriched in low molecular weight constituents. Molecular analysis evidences the presence of a complex mixture of aliphatic and aromatic O-bearing compounds, inherited from the degradation of kerogen as well as from the clay catalysed oxidation of the bitumen. These results show that (1) air oxidation is a major process in the *in situ* alteration of the organic matter of Boom clay within the HADES galleries, (2) laboratory oxidation experiments at 80 °C yield similar results as *in situ* air alteration of Boom clay and (3) artificial air oxidation may be used to assess the long term exposure of the organic matter to air.

13/01623 Kinetic analysis of the polymer burnout in ceramic thermoplastic processing of the YSZ thin electrolyte structures using model free method

Salehi, M. et al. *Applied Energy*, 2012, 95, 147–155. Polymeric binder burnout during thermoplastic processing of yttria-stabilized zirconia (YSZ) ceramics were analysed using thermogravimetric analysis (TGA). The debinding kinetics of the stearic acid/polystyrene binder have been described using model free methods and compared with the decomposition rate of the pure polymers. The apparent activation energy E_a as a function of debinding progress α was calculated in two atmospheres (argon and air) by three different methods: Ozawa–Flynn–Wall (OFW), Kissinger–Akahira–Sunose (KAS) and Friedman. The evolution of E_a with α is compatible with the evaporation of stearic acid and the unzipping and thermo-oxidative decomposition mechanisms proposed for polystyrene. The apparent activation energies obtained for the experiments under argon revealed the increased concentration of weak links in polystyrene introduced during kneading of the feedstock. Extrapolation of the kinetic parameters obtained in one run to calculate decomposition rates under different heating rates confirmed the excellent predictive power of the direct methods.

13/01624 Low temperature co-fired ceramic vaporizing liquid microthruster for microspacecraft applications

Karthikeyan, K. et al. *Applied Energy*, 2012, 97, 577–583. Low temperature co-fired ceramic (LTCC) technology is successfully employed for the first time to develop a vaporizing liquid propellant microthruster (VLM). The VLM has potential applications as micro-propulsion system for attitude control of microsatellites. The design, fabrication and testing of the LTCC-based VLM are presented. Preliminary testing is done by using water as liquid propellant. The VLM of nozzle throat size 220 $\mu\text{m} \times 200 \mu\text{m}$ produces an average thrust in the range of 34–68 μN for a flow rate of 1 mg s^{-1} with an input heater power varying from 7.1 to 9.2 W. An average specific impulse of 3.4–

6.9 s is measured. An average impulse bit of 0.67–1.4 mNs, 3.40–6.70 mNs is measured for thruster firing time of 20 s and 100 s during VLM stable mode operation at sea-level conditions.

13/01625 Performance of coupled novel triple glass and phase change material wall in the heating season: an experimental study

Kara, Y. A. and Kurnu, A. *Solar Energy*, 2012, 86, (9), 2432–2442. A Trombe wall that uses a phase change material (PCM) as the heat storage medium is usually called a PCM Trombe wall or PCM wall. A research project was conducted to investigate the performance of coupled novel triple glass (NTG) and PCM wall, which is simply called PCM wall in this paper, as a solar space heater. The south façade of a test room was constructed using PCM walls. Rubitherm® GR35 and GR41 were incorporated into the plaster of the walls as PCM. The ratio of the solar energy gain provided by the PCM walls to the heat load of the test room per month varied from 4% to 70%; daily overall efficiency of the PCM walls varied from 20% to 36%; and solar transmittance of the NTG varied from 0.45 to 0.55 during the heating period. The overall efficiency of the PCM wall including GR35 was higher than that of the PCM wall including GR41.

13/01626 Predicting changes of glass optical properties in polluted atmospheric environment by a neural network model

Verney-Carron, A. *et al. Atmospheric Environment*, 2012, 54, 141–148.

Soiling results from the deposition of pollutants on materials. On glass, it leads to an alteration of its intrinsic optical properties. The nature and intensity of this phenomenon mirrors the pollution of an environment. This paper proposes a new statistical model in order to predict the evolution of haze (H) (i.e. diffuse/direct transmitted light ratio) as a function of time and major pollutant concentrations in the atmosphere (SO_2 , NO_2 , and PM_{10} (particulate matter < 10 μm)). The model was parameterized by using a large set of data collected in European cities (especially, Paris and its suburbs, Athens, Krakow, Prague, and Rome) during field exposure campaigns (French, European, and international programmes). This statistical model, called NEUROPT-Glass, comes from an artificial neural network with two hidden layers and uses a non-linear parametric regression named multilayer perceptron. The results display a high determination coefficient ($R^2 = 0.88$) between the measured and the predicted hazes and minimizes the dispersion of data compared to existing multilinear dose–response functions. Therefore, this model can be used with a great confidence in order to predict the soiling of glass as a function of time in world cities with different levels of pollution or to assess the effect of pollution reduction policies on glass soiling problems in urban environments.

13/01627 Radiative exchange across a window and links to indoor energy demand

Frederick, J. E. and De, S. K. *Energy and Buildings*, 2012, 51, 21–28. This work examines energy exchange between a window and the external environment with emphasis on the role of radiation in determining indoor energy demand. A set of radiometers monitored the flow of solar and long-wave radiation to and from a window located in Chicago, Illinois, USA from December to July. A model of energy exchange between the atmosphere, window and interior space allows estimates of the energy required to maintain indoor temperatures. Energy is lost to the atmosphere by sensible heat transport, long-wave emission and reflection of sunlight, where the net effect of radiation is the difference between incoming and outgoing components. Sensible heat transport is the most important contributor to cooling, particularly in winter, while the direct effects of radiation are small, except in June and July. However, long-wave radiation has a significant influence on the window's temperature. Radiative processes increase the temperature contrast between the window and the atmosphere, and thereby influence sensible heat transport. For the circumstance analysed here, the action of solar and long-wave radiation during December and January increases the demand for interior heating by a factor of four over what would exist in the absence radiant energy.

13/01628 Sandblasting durability of acrylic and glass Fresnel lenses for concentrator photovoltaic modules

Nishioka, K. *et al. Solar Energy*, 2012, 86, (10), 3021–3025. The impact of sandblasting on Fresnel lenses for concentrator photovoltaic (CPV) modules must be carefully considered when CPV systems are installed in desert areas. In this study, the transmittance after sandblasting of acrylic polymethylmethacrylate (PMMA) and glass substrates was evaluated, and their durability was assessed. The transmittance decreased as the momentum of the blown sand increased. The conversion efficiency of the CPV modules was estimated using equivalent circuit calculations, and the influence of sandblasting on the output of the CPV modules was quantitatively

predicted. The coefficients of degradation for the PMMA and glass CPV modules were 0.17 and 0.08 points per unit of momentum, respectively. The durability of the CPV module with the glass Fresnel lens is approximately twice that with the PMMA lens.

13/01629 The phase stability and electrical conductivity of Bi_2O_3 ceramics stabilized by Co-dopants

Wang, S.-F. *et al. Journal of Power Sources*, 2012, 218, 106–112. In this study, Gd_2O_3 , Nb_2O_5 , Sc_2O_3 , ZrO_2 , and BaO are chosen as co-dopants with Y_2O_3 to stabilize δ phase Bi_2O_3 ceramics. Under a fixed dopant concentration, the effects of the co-dopants on the phase stability and electrical properties of $\text{Bi}_{0.76}\text{Y}_{0.24-x}\text{M}_x\text{O}_{1.5+\delta}$ ($\text{M} = \text{Gd}$, Nb , Sc , Zr , and Ba) are investigated. Based on the study results, all co-doped specimens exhibit a sintering temperature lower than that of the $\text{Bi}_{0.76}\text{Y}_{0.24}\text{O}_{1.5}$ ceramic. The $\text{Bi}_{0.76}\text{Y}_{0.24-x}\text{Gd}_x\text{O}_{1.5}$, $\text{Bi}_{0.76}\text{Y}_{0.24-x}\text{Nb}_x\text{O}_{1.5+\delta}$, and $\text{Bi}_{0.76}\text{Y}_{0.24-x}\text{Sc}_x\text{O}_{1.5}$ ceramics retain a cubic fluorite structure of $\delta\text{-Bi}_2\text{O}_3$ phase while $\text{Bi}_{0.76}\text{Y}_{0.24-x}\text{Ba}_x\text{O}_{1.5-\delta}$ displays a mixture of cubic and rhombohedral phases. Despite the fact that the ionic radius of Sc^{3+} and Zr^{4+} ions are smaller than that of Y^{3+} ion, the lattice constant of the $\text{Bi}_{0.76}\text{Y}_{0.24}\text{O}_{1.5}$ ceramic rises with the Gd_2O_3 , Sc_2O_3 , or ZrO_2 replacement but drops with the Nb_2O_5 substitution. Of the compositions studied, the $\text{Bi}_{0.76}\text{Y}_{0.26}\text{Zr}_{0.04}\text{O}_{1.5+\delta}$ ceramic emerges with the best electrical conductivities of 0.27 and 0.55 Scm^{-1} at 600 and 700 °C, much higher than those of the Y_2O_3 -doped and ZrO_2 -doped Bi_2O_3 ceramics. It is observed that, with the same total dopant concentration, the co-dopant stabilized Bi_2O_3 ceramics outperforms their single-dopant stabilized counterparts in terms of conductivity, probably due to the larger lattice constants.

13/01630 The Upper and Lower Nisyros Pumices: revisions to the Mediterranean tephrostratigraphic record based on micron-beam glass geochemistry

Tomlinson, E. L. *et al. Journal of Volcanology and Geothermal Research*, 2012, 243–244, 69–80.

The Greek island of Nisyros is the source of tephra found in distal settings throughout the Aegean. In this contribution, the authors define geochemical fingerprints for the Lower and Upper Pumice eruptions of Nisyros based on micron-beam major (EMPA) and trace (LA-ICP-MS) element data. These two eruptions are compositionally distinct from each other. The high phenocryst content of proximal Lower and Upper Pumice tephra means that the differences between the two magmas are masked in whole-rock analyses. The authors demonstrate that all previous reports of distal marine and continental tephras correspond to the younger Upper Pumice not the older Lower Pumice. This has important implications for the marine tephrochronology of the Mediterranean and for the age of the Upper and Lower Pumice eruptions. An age is suggested of at least 47 ka for the Upper Pumice and an older, unconstrained age for the Lower Pumice.

13/01631 Thermal performance and capillary limit of a ceramic wick applied to LHP and CPL

Santos, P. H. D. *et al. Applied Thermal Engineering*, 2012, 41, 92–103. The performance of a ceramic wick working as a capillary evaporator of a loop heat pipe (LHP) and a capillary pumped loop (CPL) is analysed. The LHP and the CPL have a capillary evaporator with 10 mm of inner diameter and 25 mm of length. The LHP compensation chamber has the same diameter as the evaporator and a length of 50 mm. The ceramic wick was sintered from alumina and mullite powders, achieving 50% of porosity, 1–3 μm pore size distribution and permeability of $35 \times 10^{-15} \text{ m}^2$, and then machined to properly fit the evaporators. The performance tests were carried out using deionized water as the working fluid for power inputs of up to 30 W. The thermal performance, capillary limit and area-specific thermal resistance of these systems were analysed with the support of basic heat transfer and fluid flow lumped models. The lowest area-specific thermal resistance values of 31.7 °C/W/cm² for CPL and 25.0 °C/W/cm² for LHP were reached when dissipating 3.18 W/cm², while the highest values of 52.8 °C/W/cm² for CPL and 38.8 °C/W/cm² for LHP were reached while dissipating 0.53 W/cm² and 1.06 W/cm², respectively. The analysis shows that the systems operate well at their capillary limit and their performance is equivalent to similar devices operating with acetone and ammonia reported in the literature.

13/01632 Thermal performance and pressure drop in a ceramic heat exchanger evaluated using CFD simulations

Monteiro, D. B. and de Mello, P. E. B. *Energy*, 2012, 45, (1), 489–496. There is one potential demand for heat exchangers capable of supporting high temperatures, typically higher than 800 °C, for use in thermal power plants. These heat exchangers could be used in the implementation of externally fired gas turbines cycles. To support these working conditions, during long periods of time, the heat exchanger should be constructed with adequate materials. Ceramics has been considered by many previous works as a choice. This work presents the results obtained with computational fluid dynamics (CFD) simulations of one plate-fin ceramic heat exchanger. Correlations for the Colburn

and friction factors, for a range of Reynolds number between 500 and 1500, are evaluated from the numerical results obtained with CFD. These correlations may be used for the thermal design of ceramic heat exchangers. One validation procedure is conducted comparing the simulation results with experimental data for a compact heat exchanger of similar configuration.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

13/01633 A low energy process for the recovery of bioproducts from cyanobacteria using a ball mill

Balasundaram, B. *et al. Biochemical Engineering Journal*, 2012, 69, 48–56.

Efficient and economical large scale bioprocessing of microalgae to produce a range of bio-products, working towards a biorefinery approach, is critical for the success of algal industrial biotechnology. The key process variables that affect the recovery of products from different sub-cellular locations were investigated using a high throughput cell disruption system and a cyanobacterium as model organism. This information was then used to design and test a differential recovery procedure at pilot scale using a custom designed ball mill that consumed 1.87 kWh/kg of dry biomass used approximately 34% lower than the best algal disruption system reported. The balance between the number of collisions and force of each collision between grinding media and the microorganism were manipulated to achieve differential recovery. Greater than 99% and 95% solids were recovered at the end of first and second ball milling step respectively through gravity sedimentation, an energy efficient solid-liquid separation technique. Based on these results and the release rates of intracellular and/or extracellular products tested, a theoretical framework is presented for the design of a differential recovery process using ball mills.

13/01634 An experimental study on whole paddy saccharification and fermentation for rice ethanol production

Fujieda, T. *et al. Biomass and Bioenergy*, 2012, 44, 135–141.

Whole paddy saccharification and fermentation was experimentally investigated to produce domestic bio-fuel or ethanol from rice for animal feed. More than 120 min of the high temperature soaking (HTS) promoted the gelatinization of the paddy due to an increase in the endosperm surface area. The calculated kinetic parameters evaluated based on the first-order reaction model revealed that the liquefaction and saccharification characteristics were improved by increasing the HTS time, while the roasting treatment enabled the HTS time to be shortened by 1.5 h. Fermentation combined with a longer HTS time resulted in increased ethanol production, while employing simultaneous saccharification and fermentation produced an ethanol concentration and yield of 9% and 85%, respectively, using baker's dry yeast, which was more economical than using shochu dry yeast.

13/01635 Assessment of biodiesel energy sustainability using the exergy return on investment concept

de Mora, E. F. *et al. Energy*, 2012, 45, (1), 474–480.

Biofuels are part of the current energy mix and their contribution will increase in the years to come. However, policymakers and non-governmental organizations have concerns regarding their sustainability. An adequate sustainability indicator is the energy return on investment (EROI), which evaluates the ratio of fossil energy consumption during their production. This paper applies the exergy cost theory to different biodiesel production pathways, from crop cultivation to the production plant, in order to check if this principle is achieved using exergy instead of energy. For this purpose, it introduces a new sustainability indicator, called ExROI, defined as the ratio between the exergy of a particular resource and the amount of exergy required to obtain it. In other words, using exergy terms it tries to answer to the question: How much biodiesel would be needed to produce 1 kg of biodiesel? The paper demonstrates that the usual biodiesel production pathways are sustainable in this sense, although measures must be taken to decrease the rate of non-renewable energy consumption in the process, in order to make them economically competitive too.

13/01636 Asymmetric adjustments in the ethanol and grains markets

Chang, C.-L. *et al. Energy Economics*, 2012, 34, (6), 1990–2002.

This paper examines the long- and short-run asymmetric adjustments and pairs trades for nine pairs of spot and futures prices, itemized as three own pairs for three different bio-fuel ethanol types, three own pairs for three related agricultural products, namely corn, soybeans and sugar, and three cross pairs that included hybrids of the spot price of each of the agricultural products and an ethanol futures price. Most of the spreads' asymmetric adjustments generally occur during narrowing. The three ethanol pairs that contain the eCBOT futures with each of Chicago spot, New York Harbor spot and Western European (Rotterdam) spot show different long-run adjustments, arbitrage profitable opportunities and price risk hedging capabilities. The asymmetric spread adjustments for the three grains are also different, with corn spread showing the strongest long-run widening adjustment, and sugar showing the weakest narrowing adjustment. Among others, the empirical analysis indicates the importance of potentially hedging the spot prices of agricultural commodities with ethanol futures contracts, which sends an important message that the ethanol futures market is capable of hedging price risk in agricultural commodity markets. The short-run asymmetric adjustments for individual prices in the nine pairs, with the exception of the corn own pair, underscore the importance of futures prices in the price discovery and hedging potential, particularly for ethanol futures.

13/01637 Biofuel supply chain design under competitive agricultural land use and feedstock market equilibrium

Bai, Y. *et al. Energy Economics*, 2012, 34, (5), 1623–1633.

The rapid expansion of the biofuel industry diverts a large amount of agricultural crops as energy feedstocks, and in turn affects farm land allocation, feedstock market equilibrium, and agricultural economic development in local areas. This paper proposes game-theoretic models that incorporate farmers' decisions on land use and market choice into the biofuel manufacturers' supply chain design problem. A non-cooperative bi-level Stackelberg leader–follower game model and a cooperative game model are developed respectively to address possible business partnership scenarios between feedstock suppliers and biofuel manufacturers. The models determine the optimal number and locations of biorefineries, the required prices for these refineries to compete for feedstock resources, as well as farmers' land use choices between food and energy. Using corn as an example of feedstock crops, spatial market equilibrium is utilized to model the relationship between corn supply and demand, and the associated price variations in local grain markets. With linear corn demand functions, the authors develop a solution approach that transforms the original discrete mathematical program with equilibrium constraints (DC-MPEC) into a solvable mixed integer quadratic programming (MIQP) problem based on Karush–Kuhn–Tucker (KKT) conditions. The proposed methodology is illustrated using an empirical case study of the Illinois State. The computation results reveal interesting insights into optimal land use strategies and supply chain design for the emerging 'biofuel economy'.

13/01638 Biohydrogen production from co-digestion of cow manure and waste milk under thermophilic temperature

Lateef, S. A. *et al. Bioresource Technology*, 2012, 110, 251–257.

Biohydrogen production from co-digestion of cow manure (M) and waste milk (WM), milk from mastitis cows treated with cefazolin, was evaluated in a 3×5 factorial design. Organic loading of 20, 40 and 60 g volatile solid (VS) L^{-1} were tested at temperature of 55 °C using M:WM (VS/VS) 70:30, 50:50, 30:70, 10:90 and 0:100. Hydrogen production increased with organic loading and M:WM to a maximum of 59.5 mL g^{-1} VS fed at 40 g VSL^{-1} in M:WM 70:30. Butyrate was the main volatile fatty acid (VFA) accumulated in M:WM 50:50, 30:70 and 10:90. Overall reduction of more than 90% of cefazolin resistant bacteria was observed in all the treatments. The reduction was higher at 40 and 60 than 20 g VSL^{-1} ($P < 0.05$). Inclusion of waste milk enhances hydrogen production from cow manure and could offer added benefit of waste milk treatment and disposal.

13/01639 Characterization of microalga *Nannochloropsis* sp. mutants for improved production of biofuels

Anandarajah, K. *et al. Applied Energy*, 2012, 96, 371–377.

To select microalgae with a high biomass, chlorophyll *a*, lipid, and fatty acid content of two mutants (LARB-202-2 and LARB-202-3) and their parent wild type of the unicellular green alga *Nannochloropsis* sp were cultured with air containing 1% CO_2 for a week in 1 L bubbled tubes with continuous illumination at 140 or 300 μmol photons $m^{-2} s^{-1}$. Overall biomass productivity of all three strains were higher under high light (HL, 300 μmol photons $m^{-2} s^{-1}$) with LARB-202-3 achieving the highest volumetric productivity (0.9 $g L^{-1} d^{-1}$) and parent wild type the lowest (0.72 $g L^{-1} d^{-1}$) when cultured for 6 days with medium nitrogen level. Biomass productivity of all three strains were found to be substantially lower in response to low light (LL, 140 μmol photons $m^{-2} s^{-1}$) growth conditions. However, LARB-202-3 showed

the highest biomass productivity ($0.74 \text{ g L}^{-1} \text{ d}^{-1}$) under LL conditions too. LARB-202-3 possessed high photosynthetic productivity as measured by chlorophyll *a* (Chl *a*) content under HL conditions throughout the growth period. The content of Chl *a* declined gradually in all three tested strains over time. Volumetric productivity of biomass was closely associated with the cellular content of Chl *a*. Total lipid productivity of LARB-202-2 and LARB-202-3 grown in low nitrogen media for 12 days were 273 and $297 \text{ mg L}^{-1} \text{ d}^{-1}$, respectively, while that of wild type parent was $244 \text{ mg L}^{-1} \text{ d}^{-1}$. Major medium chain fatty acids (e.g. C14:0 and C16:0) make up nearly 63% of total fatty acids in all three strains. No significant variation in major fatty acid composition was found among the tested mutants and the wild type parent. The mutants are discussed in terms of their comparative advantage over their wild type parent with respect to their potential utilization by the algal biotechnology industry for the production of biofuels.

13/01640 Co-production of electricity and ethanol, process economics of value prior combustion

Treasure, T. *et al. Energy Conversion and Management*, 2012, 62, 141–153.

A process economic analysis of co-producing bioethanol and electricity (value prior to combustion) from mixed southern hardwood and southern yellow pine is presented. Bioethanol is produced by extracting carbohydrates from wood via autohydrolysis, membrane separation of byproducts, enzymatic hydrolysis of extracted oligomers and fermentation to ethanol. The residual solids after autohydrolysis are pressed and burned in a power boiler to generate steam and electricity. A base case scenario of biomass combustion to produce electricity is presented as a reference to understand the basics of bio-power generation economics. For the base case, minimum electricity revenue of \$70–\$96/MWh must be realized to achieve a 6–12% internal rate of return. In the alternative co-production cases, the ethanol facility is treated as a separate business entity that purchases power and steam from the biomass power plant. Minimum ethanol revenue required to achieve a 12% internal rate of return was estimated to be \$0.84–\$1.05/litre for hardwood and \$0.74–\$0.85/litre for softwood. Based on current market conditions and an assumed future ethanol selling price of \$0.65/litre, the co-production of cellulosic bioethanol and power does not produce financeable returns. A risk analysis indicates that there is a probability of 26.6% to achieve an internal rate of return equal or higher than 12%. It is suggested that focus be placed on improving yield and reducing CAPEX before this technology can be applied commercially. This modelling approach is a robust method to evaluate economic feasibility of integrated production of bio-power and other products based on extracted hemicellulose.

13/01641 Combined hydrogen and ethanol production from sugars and lignocellulosic biomass by *Thermoanaerobacterium* AK₅₄, isolated from hot spring

Sigurbjornsdottir, M. A. and Orlygsson, J. *Applied Energy*, 2012, 97, 785–791.

Combined biohydrogen and bioethanol (CHE) production from monosugars, polymeric carbohydrates and hydrolysates made from various lignocellulosic biomasses was investigated by strain AK₅₄, a saccharolytic, thermophilic ethanol and hydrogen producing bacterium isolated from a hot spring in Iceland. Optimum growth conditions for the strain were between pH 5.0–6.0 and at 65 °C. As determined by full 16S rRNA analysis, strain AK₅₄ belongs to the genus *Thermoanaerobacterium*, most closely affiliated with *Th. aciditolerans* (99.0%). Effect of increased initial glucose concentration on growth and end product formation was investigated and good correlations were observed between increased substrate loadings and end product formation of up to 50 mM where clear inhibition was shown. The ability to utilize various carbon substrates was tested with positive growth on xylose, glucose, fructose, mannose, galactose, sucrose and lactose. The major end products in all cases were ethanol, acetate, lactate, hydrogen and carbon dioxide. By lowering the partial pressure of hydrogen during glucose degradation, the end product formation was directed towards hydrogen, acetate and ethanol but away from lactate. Hydrogen and ethanol production from hydrolysates from biomass (7.5 g L^{-1} (dw)); cellulose, newspaper, grass (*Phleum pratense*), barley straw (*Hordeum vulgare*), and hemp (*Cannabis sativa* L.) was investigated. The biomass was chemically (acid/alkali) and enzymatically pretreated. The highest ethanol production was observed from cellulose hydrolysates (24.2 mM) but less was produced from lignocellulosic biomasses. Chemical pretreatment of biomass hydrolysates increased hydrogen and ethanol yields substantially from barley straw, hemp and grass but not from cellulose or newspaper. The highest hydrogen was also produced from cellulose hydrolysates or $6.7 \text{ mol-H}_2 \text{ g}^{-1}$ TS pretreated with alkali ($12.2 \text{ mol-H}_2 \text{ g}^{-1}$ glucose equivalents) but of the lignocellulosic biomass, highest yields were from grass pretreated with base ($4.9 \text{ mol-H}_2 \text{ g}^{-1}$ TS).

13/01642 Current biodiesel production technologies: a comparative review

Abbaszaadeh, A. *et al. Energy Conversion and Management*, 2012, 63, 138–148.

Despite the high energy demand in the industrialized world and the pollution problems caused by widespread use of fossil fuels, the need for developing renewable energy sources with less environmental impacts are increasing. Biodiesel production is undergoing rapid and extensive technological reforms in industries and academia. The major obstacle in production and biodiesel commercialization path is production cost. Thus, in previous years numerous studies on the use of technologies and different methods to evaluate optimal conditions of biodiesel production technically and economically have been carried out. In this paper, a comparative review of the current technological methods so far used to produce biodiesel has been investigated. Four primary approaches to make biodiesel are direct use and blending of vegetable oils, micro-emulsions, thermal cracking (pyrolysis) and transesterification. Transesterification reaction, the most common method in the production of biodiesel, is emphasized in this review. The two types of transesterification process; catalytic and non-catalytic are discussed at length in the paper. Both advantages and disadvantages of the different biodiesel production methods are also discussed.

13/01643 Discrimination of biodiesel blends with ^1H NMR spectroscopy and principal component analyses

Flores, I. S. *et al. Fuel*, 2012, 99, 40–44.

The use of ^1H nuclear magnetic resonance (NMR) in combination with principal component analysis (PCA) is proposed, for the first time, to discriminate methyl biodiesel from different sources. Sixty-six samples, either pure or combined into binary blends of biodiesel from castor, cotton, peanut, pinion, soybean and tallow were used in this study. The PCA of the selected regions in ^1H NMR spectra proved to be a powerful tool for determining biodiesel present in blends, and it was also very effective in identifying their sources. Furthermore, by selecting appropriate regions in ^1H NMR spectra, it was possible to predict the biodiesel with different fatty acid methyl esters (FAME) compositions and contents in blends. Moreover, it was possible to correlate the biodiesel composition with properties such as viscosity and crystallization temperature of the FAME blends. However, due to similarities in the fatty acid content and the absence of notable spectral differences in ^1H NMR, it was not possible to distinguish pinion and peanut biodiesel blends. These blends were separated of the analysed group by elimination criteria, and their pure biodiesel (B100) was identified by the characteristic allylic hydrogen chemical shifts for the linoleic esters.

13/01644 Effects of biofuel from fish oil industrial residue – diesel blends in diesel engine

Mrad, N. *et al. Energy*, 2012, 44, (1), 955–963.

The present work aims to produce biofuel from fish oil industrial residue and to test the biofuel in diesel engine. A 4.5 kW at 1500 rpm single cylinder air cooled direct injection diesel engine was used for the present experimental work. The experimental results show that the brake thermal efficiency marginally increases with biofuel from 29.98% (neat diesel) to the maximum of 32.4% with biofuel at 80% of maximum load. Also experiments were conducted with different blends of biofuel and diesel (B20 and B40). Though the NO_x emissions are high with neat biofuel and blends, the other emissions like CO, HC and particulate matter (PM) are decreased. The PM emissions decrease when the percentage biofuel increases in the blend. It reduces from 8271 ng/s with neat diesel to 8137 ng/s with B40. It further reduces to the minimum of 7842 ng/s with neat biofuel. The cylinder peak pressure increases as the biofuel quantity increases in the blend. The rate of premixed combustion increases with neat biofuel and its blends than neat diesel. Addition of biofuel with diesel decreases the combustion duration and ignition delay due to higher cetane number of biofuel.

13/01645 Effects of mechanical pre-treatment on the biogas yield from ley crop silage

Lindmark, J. *et al. Applied Energy*, 2012, 97, 498–502.

Previous studies on substrates for biogas production have shown that different types of pre-treatments make the material more accessible for microbial degradation by breaking down the complex structure of the organic material, thereby increasing their potential for gas production. In this paper, two different mechanical pre-treatment apparatus, i.e. a Grubben deflaker (Gd) and a Krümm disperser (Kd), were tested in a full-scale setup to evaluate their effects on ley crop silage. The treatments were investigated with regard to their effects on particle size, methane potential, capacity and energy balance. The results after 115 days of incubation in a batch assay show that methane production increased by 59% and 43%, respectively, after grinding with Gd and Kd. In both treatments, 90% of the ley crop was ground to particles of less than 2 mm and more than 50% of the sample was reduced to particles smaller than 0.125 mm. The energy balance was positive for Gd and around the break-even point for Kd. Analysis of the setup

showed that Kd had almost twice the capacity of the Gd. If installed in the co-digestion biogas plant Växtkraft in Västerås, Sweden, the Gd and Kd could increase annual biogas yields by 790 MW h and 585 MW h respectively.

13/01646 Emissions of N₂O and CH₄ from agricultural soils amended with two types of biogas residues

Odlare, M. *et al. Biomass and Bioenergy*, 2012, 44, 112–116. Biogas residues contain valuable plant nutrients, important to the crops and also to soil microorganisms. However, application of these materials to the soils may contribute to the emission of greenhouse gases (GHG) causing global warming and climate change. In the present study, incubation experiment was carried out, where the emission rates of N₂O and CH₄ were measured after amending two soils with two types of biogas residues: (1) a regular residue from a large-scale biogas plant and (2) a residue from an ultra-filtration membrane unit connected to a pilot-scale biogas plant (BRMF). The emissions of N₂O and CH₄ were measured at two occasions: at 24 h and at 7 days after residue amendment, respectively. Amendment with filtered biogas residues (BRMF) led to an increase in N₂O emissions with about 6–23 times in organic and clay soil, respectively, in comparison to unfiltered biogas residues. Methane emission was detected in small amounts when filtered biogas residue was added to the soil. Amendment of unfiltered biogas to the organic soil resulted in net consumption. In conclusion, fertilization with BRMF can be combined with risk of an increase N₂O emission, especially when applied to organic soils. However, in order to transfer these results to real life agriculture, large scale field studies need to be carried out.

13/01647 Energy use in cropping systems: a regional long-term exploratory analysis of energy allocation and efficiency in the Inland Pampa (Argentina)

Ferraro, D. F. *Energy*, 2012, 44, (1), 490–497. As agricultural system comprises natural processes that are ruled by thermodynamics, the energy utilization is well suited for assessing the sustainability in the management of natural resources. The goals of this paper are: (1) to assess the energy use efficiency of the main crops during the 1992–2005 period in Inland Pampa (Argentina); (2) to evaluate the database structure in terms of energy allocation; (3) to assess the changes in technical efficiency using frontier analysis and (4) to identify the best explanatory variables for energy efficiency variability. Results showed an upward trend in productivity per unit area in the crops analysed (excluding sunflower). Summer soybean and sunflower showed higher energy efficiency values by the end of time series. The main shift in the energy use pattern was the reduction of the energy allocated to tillage. The overall performance of the wheat and soybean crops in the study area appears to be closer to the energy usage pattern shown by the top 5% energy use efficiency crop fields. The exploratory analysis using classification and regression trees revealed that the energy allocation to tillage; and the crop specie were the attributes that mainly explained the energy efficiency changes.

13/01648 Ethanol production from *Eucalyptus* plantation thinnings

McIntosh, S. *et al. Bioresource Technology*, 2012, 110, 264–272. Conditions for optimal pretreatment of eucalypt (*Eucalyptus dunnii*) and spotted gum (*Corymbia citriodora*) forestry thinning residues for bioethanol production were empirically determined using a 3³ factorial design. Up to 161 mg/g xylose (93% theoretical) was achieved at moderate combined severity factors (CSF) of 1.0–1.6. At CSF > 2.0, xylose levels declined, owing to degradation. Moreover at high CSF, depolymerization of cellulose was evident and corresponded to glucose (155 mg/g, ~33% cellulose) recovery in prehydrolysate. Likewise, efficient saccharification with Cellic[®] CTec 2 cellulase correlated well with increasing process severity. The best condition yielded 74% of the theoretical conversion and was attained at the height of severity (CSF of 2.48). *Saccharomyces cerevisiae* efficiently fermented crude *E. dunnii* hydrolysate within 30 h, yielding 18 g/L ethanol, representing a glucose to ethanol conversion rate of 0.475 g/g (92%). Based on these findings, eucalyptus forest thinnings represent a potential feedstock option for the emerging Australian biofuel industry.

13/01649 Evaluation of industrial *Saccharomyces cerevisiae* strains for ethanol production from biomass

Kasavi, C. *et al. Biomass and Bioenergy*, 2012, 45, 230–238. Five industrial *Saccharomyces cerevisiae* strains were evaluated for their suitability for strain improvement for future use in ethanol production processes. Principal components analysis of growth-related and production-related fermentation parameters of the five strains grown on glucose demonstrated the superiority of the Y9 strain in terms of its rapid growth and highest ethanol yields on both biomass and glucose. The growth and ethanol production performances of these strains on various agro-industrial wastes (including sugar beet pulp, starch and sugar beet molasses) and biological residues (including carrot, tomato and potato peel) were also determined. Ethanol

tolerance studies, using both solid and liquid cultures, revealed the remarkable abilities of the BC187 and Y9 strains to survive and grow at high ethanol concentrations. Suspension cultures were found to be highly tolerant to 78.80 g L⁻¹ ethanol however their growth ability showed a distinct decrease with increasing ethanol concentration such that only (1–2)% of the control growth was observed in media containing 118.20 g L⁻¹ ethanol. The importance of choosing the appropriate *S. cerevisiae* strain to be used in ethanol production was clearly established with this study. Fermentation performances of the cultures under different cultivation conditions pointed to the fact that the choice of strain will not only depend on the ethanol tolerance but also on the preferential utilization of the carbon resources of biological residues.

13/01650 GIS based assessment of rice (*Oryza sativa*) straw biomass as an alternative fuel for tea (*Camellia sinensis* L.) drying in Sonitpur district of Assam, India

Hiloidhari, M. *et al. Biomass and Bioenergy*, 2012, 44, 160–167. This paper presents a study on spatial distribution of rice (*Oryza sativa*) straw and its potential demand as a renewable energy fuel for tea (*Camellia sinensis* L.) drying. Rice straw availability and its demand in tea gardens are estimated using IRS-P6 LISS III remote sensing data in GIS environment. Shortest road transportation network is designed to ascertain that rice straw is delivered in the tea gardens with minimum transportation cost. Costs of production and harvesting of rice straw are also assessed and incorporated in the overall procurement cost of rice straw biomass. It is observed that the degree of fulfilment of thermal energy demand for tea drying through rice straw is spatially varying. It is also found that straw biomass can economically compete with coal as a source of thermal energy in tea drying and contribute to the farmers earning from otherwise waste straw, if coal equivalent price is fixed for straw. The coal equivalent cost of straw could be raised up to \$37.04/t which would enhance farmers profit up to \$18.26/t.

13/01651 Microalgae: an alternative as sustainable source of biofuels?

Amaro, H. M. *et al. Energy*, 2012, 44, (1), 158–166. In recent decades, the world has been confronted with an energy crisis associated with irreversible depletion of traditional sources of fossil fuels, coupled with atmospheric accumulation of greenhouse gases that cause global warming. The urgent need to replace traditional fuels led to emergence of biodiesel and biohydrogen as interesting alternatives, both of which can be obtained via microalga-mediated routes. Microalgae are ubiquitous eukaryotic microorganisms, characterized by a remarkable metabolic plasticity. Their oil productivities are much higher than those of higher terrestrial plants, and they do not require high quality agricultural land. Microalgae may indeed be cultivated in brackish and wastewaters that provide suitable nutrients (e.g. NH₄⁺, NO₃⁻ and PO₄³⁻), at the expense of only sunlight and atmospheric CO₂. On the other hand, metabolic engineering permits release of molecular hydrogen also via photosynthetic routes, which will easily be converted to electricity in fuel cells or mechanical power in explosion engines, with only water vapour as exhaust product in both cases. However, large-scale implementation of microalga-based systems to manufacture biodiesel and biohydrogen has been economically constrained by their still poor volumetric efficiencies, which imply excessively high costs when compared with current petrofuel prices. Technological improvements are accordingly critical, both on the biocatalyst and the bioreactor levels. The current bottlenecks that have apparently precluded full industrial exploitation of microalga cells are critically discussed here, namely those derived from the scarce knowledge on the mechanisms that control regulation of gene expression, the reduced number of species subjected to successful genetic transformation, the relatively low cell density attainable, the poor efficiency in harvesting, and the difficulties in light capture and use. Therefore, this paper provides an overview of the feasibility of microalgae for production of biofuels via synthesis of liquid endocellular metabolites (i.e. triglycerides) and gaseous extracellular ones (i.e. molecular hydrogen), and addresses technical and economic shortcomings and opportunities along the whole processing chain, at both microorganism and reactor levels.

13/01652 Paulownia as raw material for solid biofuel and cellulose pulp

López, F. *et al. Biomass and Bioenergy*, 2012, 45, 77–86. The influence of the process conditions of pulping of a trihybrid clone *Paulownia* on pulp properties in the soda-anthraquinone process has been investigated. A composite central experimental design and a multiple regression were used to find the relationship between independent process variables and pulp properties. The ash content (8.9 g kg⁻¹) is lower and cellulose content (440 g kg⁻¹) is higher than those found for other species of *Paulownia* and other energetic crops. The elemental composition has a low content in S and N (2.1 g kg⁻¹) in comparison with poplar or willow. With a gross heating value of

20.3 MJ kg⁻¹. This is somewhat higher than those for hardwood, slightly higher than those for *Pinus pinaster* and softwood, and much higher than those for residues of food plants and agricultural crops. This supports the use of the genus *Paulownia* as an energy crop. Fibre length (0.97 mm) is similar to hardwoods and suitable physical characteristics of paper sheets (tensile index) and acceptable chemical characteristics and yield pulping could be obtained by operating at low-intermediate temperature (163–171 °C) and alkali concentration (200 g kg⁻¹) and high or medium values for operation time (120–150 min). The pulp obtained at these conditions has suitable chemical (pulp) and physical (paper sheets) characteristics: yield (470 g kg⁻¹), ethanol-benzene extractives (22.2 g kg⁻¹), holocellulose contents (960 g kg⁻¹), α -cellulose contents (758 g kg⁻¹), lignin contents (82.8 g kg⁻¹), Shopper–Riegler degree (23.2 °SR), and tensile index (36.0 kN m kg⁻¹).

13/01653 Physical quality changes during the storage of canola (*Brassica napus* L.) straw pellets

Chico-Santamarta, L. *et al. Applied Energy*, 2012, 95, 220–226.

Brassica napus L. (canola/oilseed rape) straw presents a suitable alternative combustion fuel due to its availability, relatively high calorific value and low moisture content. Pelletization enabled the bulk density of canola straw to be improved, enhancing its potential as an alternative combustion fuel. The aim of the research was to study the changes in the quality properties (i.e. abrasion resistance, compressive strength, particle density and pellet dimensions) of canola straw pellets during storage over a period of 48 weeks. The storage of canola straw pellets did not affect the abrasion resistance of the pellets. While the particle density and compressive strength varied with length of pellet storage, no trend in these variations was observed. The length of the pellets decreased during storage due to breakage, while the diameter did not vary during storage.

13/01654 Potentials of lignocellulosic bioethanols produced from hardwood in Taiwan

Ko, C.-H. *et al. Energy*, 2012, 44, (1), 329–334.

Their fast growth and adaptability make hardwoods good candidates for bioethanol production. This study evaluated acacia and eucalypt for bioethanol production in Taiwan. Enzyme formulations with endoglucanase, cellobiohydrolases and xylanase activities were applied for subsequent saccharification. The hydrolysis efficiencies were negatively impacted by the lignin contents of pulps. SSF (simultaneous saccharification and fermentation) were also conducted using *Saccharomyces cerevisiae* D5A. After 170 h, 70.72 and 65.21 g of ethanol (per kg oven-dried wood) were produced from acidic exploded acacia and eucalypt pulps, respectively. In addition, 44.50 and 42.27 g of ethanol (per kg oven-dried wood) were produced from unbleached acacia and eucalypt kraft pulps, respectively. The overall potential of bioethanol production from the hardwoods in Taiwan was also estimated.

13/01655 Temperature control in energy grass pellet production – effects on process stability and pellet quality

Larsson, S. H. and Rudolfsson, M. *Applied Energy*, 2012, 97, 24–29. Pilot scale ring and die pelletizing of reed canary grass (*Phalaris arundinacea* L.) was performed in experimental designs for screening and optimization of pellet quality parameters bulk density and durability and for determination of specific energy consumption under different settings. Control variables included die temperature, raw material moisture content, and steam conditioning. By using a unique experimental setup, where die temperature could be controlled, all factors could be varied independently. Results from the screening design, showed that a low die temperature was necessary to avoid discontinuous production conditions and guided the choice of settings in the optimization design for obtaining high pellet quality. Settings for reaching the suggested quality criteria of pellets for non-industrial use with a durability $\geq 97.5\%$ and a bulk density of ≥ 600 kg/m³ were easiest to meet at die temperatures around 30 °C and a material temperature of approximately 30–40 °C (equal to 2–4 kg steam/h) for the full range of raw material moisture content (12–16%).

13/01656 Thermodynamic analysis of algal biocrude production

Beal, C. M. *et al. Energy*, 2012, 44, (1), 925–943.

Although algal biofuels possess great potential, profitable production is quite challenging. Much of this challenge is rooted in the thermodynamic constraints associated with producing fuels with high energy, low entropy, and high energy from dispersed materials. In this study, a preliminary thermodynamic analysis is presented that calculates the energy, entropy, and exergy of the intermediate products for algal biocrude production. These values are also used in an initial attempt to characterize the thermodynamic efficiency of that system. The production pathway is simplified by assuming ideal solutions throughout. Results for the energy and exergy efficiencies, and the first-order energy and exergy return on investment, of the system are given. The summary finding is that the first-order energy return on investment in the best case considered could be as high as 520, as compared to

1.7×10^{-3} in the experimental unit under development. While this analysis shows that significant improvement may be possible, the ultimate thermodynamic efficiency of algal biofuels likely lies closer to the moderate case examined here, which yielded a first-order energy return on investment of 10. For perspective, the first-order energy return on investment for oil and gas production has been estimated in the literature to be ~ 35 .

13/01657 Torrefaction and low-temperature carbonization of woody biomass: evaluation of fuel characteristics of the products

Park, S.-W. *et al. Energy*, 2012, 45, (1), 676–685.

Preprocessing of woody biomass was performed with torrefaction and low-temperature carbonization. In this study, the pretreated samples have been used to evaluate the energy yield and fuel characteristics. The combustion profiles of the torrefied sample and the low-temperature carbonized sample blended with coal were examined in order to analyse the characteristics of co-combustion. Energy yields of 80–98% in torrefied samples and 46–63% in low-temperature carbonized samples were observed. It was found that in the low-temperature carbonization zone, the coal band moved toward that of coal. The number of differential thermogravimetric peaks decreased from two to one with an increase in the thermal-treatment temperature. In the case of samples blended with coal and low-temperature carbonized samples at 350 °C, it has been confirmed that the activation energy and all index parameters decreased as the blend ratio increased. It was confirmed that as a result, the combustion rate (da/dt) became higher owing to an increased value of the constant (k), which represents the reaction rate. However, in the case of the sample torrefied at 275 °C, it was confirmed that the combustion rate was not the same, according to the co-combustion ratio, because of an opposite tendency shown in the devolatilization and char combustion stages.

Geothermal energy

13/01658 Contribution of ground surface altitude difference to thermal anomaly detection using satellite images: application to volcanic/geothermal complexes in the Andes of central Chile

Gutiérrez, F. J. *et al. Journal of Volcanology and Geothermal Research*, 2012, 237–238, 69–80.

Detection of thermal anomalies in volcanic–geothermal areas using remote sensing methodologies requires the subtraction of temperatures, not provided by geothermal manifestations (e.g. hot springs, fumaroles, active craters), from satellite image kinetic temperature, which is assumed to correspond to the ground surface temperature. Temperatures that have been subtracted in current models include those derived from the atmospheric transmittance, reflectance of the Earth's surface (albedo), topography effect, thermal inertia and geographic position effect. The authors propose a model that includes a new parameter (K) that accounts for the variation of temperature with ground surface altitude difference in areas where steep relief exists. The proposed model was developed and applied, using ASTER satellite images, in two Andean volcanic–geothermal complexes (Descabezado Grande–Cerro Azul volcanic complex and Planchón–Peteroa–Azufre volcanic complex) where field data of atmosphere and ground surface temperature as well as radiation for albedo calibration were obtained in 10 selected sites. The study area was divided into three zones (northern, central and southern zones) where the thermal anomalies were obtained independently. K value calculated for night images of the three zones are better constrained and resulted to be very similar to the environmental lapse rate (ELR) determined for a stable atmosphere ($ELR > 7$ °C/km). Using the proposed model, numerous thermal anomalies in areas of ≥ 90 m $\times$ 90 m were identified that were successfully cross-checked in the field. Night images provide more reliable information for thermal anomaly detection than day images because they record higher temperature contrast between geothermal areas and its surroundings and correspond to more stable atmospheric condition at the time of image acquisition.

13/01659 Effect of a superheating and sub-cooling heat exchanger to the performance of a ground source heat pump system

Bakirci, K. and Colak, D. *Energy*, 2012, 44, (1), 996–1004.

The aim of this study is to evaluate the effect of a superheating and sub-cooling heat exchanger (SHCHE) to the performance of ground source heat pump system for climatic condition of Erzurum having cold climate in Turkey. For this purpose, an experimental set-up was constructed. The experimental apparatus consists of a series ground heat exchanger, a liquid-to-liquid vapour compression heat pump, water circulating pumps and other measurement equipment. In this

study, the performance of the systems with and without SHCHE was experimentally investigated. The experiments were performed in 2010 for January and February which are the coldest months of the heating season. The experimentally obtained results were used to calculate the power values of the main system equipment, the coefficient of performance of the heat pump and the overall system for systems with and without SHCHE.

13/01660 Environomic optimal configurations of geothermal energy conversion systems: application to the future construction of enhanced geothermal systems in Switzerland

Gerber, L. and Maréchal, F. *Energy*, 2012, 45, (1), 908–923.
The development of enhanced geothermal systems (EGS) for the cogeneration of electricity and district heating is expected to be important in the future. The criteria to be accounted for in the energy conversion system design are the economic profitability, the thermodynamic efficiency in the usage of the resource, and the generated life-cycle environmental impacts, which are as well a key point for the public acceptance of geothermal energy. This paper presents a systematic methodology for the optimal design and configuration of geothermal systems considering environomic criteria. Process design and process integration techniques are used in combination with life cycle assessment (LCA) and multi-objective optimization techniques, using a multi-period strategy to account for the seasonal variations in the district heating demand. It is illustrated by an application to the future EGS construction for cogeneration in the context of Switzerland. Different conversion cycles are considered: single and double-flash systems, organic Rankine cycles (ORC), and Kalina cycles. The optimal configuration is determined at each construction depth for the EGS from 3000 down to 10,000 m and at each district heating network installed capacity from 0 to 60 MW_{th}. Results show that in the shallowest range of depths (3500–6000 m), the optimal configurations for all considered performance indicators are EGS between 5500 and 6000 m with a Kalina cycle for cogeneration, and a district heating network with an installed capacity between 20 and 35 MW_{th}. In the deepest range (7500–9500 m), when compared with the single electricity production, the cogeneration of district heating is less favourable from an economic and exergetic perspective (11% and 17% of relative penalty, respectively, for a district heating network with an installed capacity of 60 MW_{th}) but more favourable in terms of environmental performance (37% of relative improvement for avoided CO₂ emissions).

13/01661 Experimental study on geothermal heat exchangers buried in diaphragm walls

Xia, C. *et al. Energy and Buildings*, 2012, 52, 50–55.
To bury absorber tubes in diaphragm wall as heat exchanger is a new energy saving technology. This paper is dedicated to study this new technology based on the field experiment at Shanghai Museum of Natural History. By the experiment, the heat transfer performance of heat exchanger in diaphragm wall and its impact factors including heat exchanger type, water velocity, inlet water temperature and operation mode were investigated. The test results show that (i) the heat exchange rate of W-shaped heat exchanger reached to 66.3 and 73.7 W/m for tube type (a) and (b) at the inlet temperature of 35 °C, which are approximately 1.2–1.4 times higher than that of single U-shaped type (c); (ii) under the experimental conditions, the reasonable water velocity is 0.6–0.9 m/s; (iii) the exchange rate reached to 40.3, 66.3 and 85.0 W/m at the inlet temperature of 32, 35 and 38 °C, respectively, for tube type (a), every 1 °C rise of inlet water will promote 15% heat exchange rate; (iv) in intermittent operation mode, the average heat exchange rate is 82.8 W/m while 72.7 W/m for continuous mode under the experimental condition, i.e. 14.7% higher than that in continuous mode.

13/01662 Heat-source solutions to heat conduction in anisotropic media with application to pile and borehole ground heat exchangers

Li, M. and Lai, A. C. K. *Applied Energy*, 2012, 96, 451–458.
This work analyses influence of anisotropy of anisotropic soil on the processes of heat transfer by ground heat exchangers used in ground-coupled heat pump systems. First, this paper uses the heat-source theory to develop several explicit exact solutions for heat conduction in anisotropic infinite or semi-infinite media with internal line, cylindrical-surface, or spiral-line sources. These solutions will reduce to common heat-source solutions for isotropic media. Next, these general solutions are applied to borehole ground heat exchangers and energy piles (or pile ground heat exchangers). Then, temperature responses of borehole and pile ground heat exchangers are examined in depth. Especially, the cylindrical-surface source model and the spiral-line source model are compared when applied to energy piles with spiral coils. An interesting result of this comparison is that these two models yield the almost same average temperature at the pile wall, implying these two models should be equivalent for modelling responses of

energy piles with spiral coils. However, compared to the cylindrical-surface model, spiral-line model is physically reasonable but is computation-intensive. Moreover, the theoretical analysis shows that anisotropy of the medium has little effect on the short-term performance of ground heat exchangers but influences the long-term temperature responses obviously.

13/01663 Measuring two-phase flow in geothermal pipelines using sharp edge orifice plates

Helbig, S. and Zarrouk, S. J. *Geothermics*, 2012, 44, 52–64.
The measurement of the two-phase flow rate is very important for the geothermal industry. Among the many different measurement techniques available, the orifice plate stands out for its simplicity, low cost, and the ability to provide real time measurements. Several data sets from different geothermal fields in New Zealand, Indonesia, and the Philippines are used to evaluate existing correlations all of which are based on homogenous flow models. Then derive and test a new correlation based on separated flow model with time discrete liquid phase flow for a more accurate measurement of two-phase flow in geothermal pipelines using the orifice plate. The new correlation is now being implemented successfully in New Zealand and other countries.

13/01664 Numerical simulation of salt precipitation in the fractures of a CO₂-enhanced geothermal system

Borgia, A. *et al. Geothermics*, 2012, 44, 13–22.
The development of enhanced geothermal systems using CO₂ (CO₂-EGS) is a promising idea for expanding geothermal energy production (especially in areas with scarce water resources) when large supplies of captured anthropogenic CO₂ may be available in the future. Implementing this concept relies on replacing the natural geothermal brine in the reservoir with injected CO₂ to achieve enhanced energy recovery, and raises the questions of the fate of dissolved salts in the brine as CO₂ dries out the system, and how any precipitated salt could affect fluid flow. In this case, a new TOUGH2 equation of state module (ECO₂H) was used to simulate CO₂ injection in an EGS with a brine system comprised of H₂O and NaCl. This so called CO₂-EGS reservoir is at a depth of 3.5–4.5 km with normal pressure (hydrostatic) and temperature (160–200 °C) gradients. A classic 'five-well' geometry is assumed in the 706 m × 706 m × 1 km block, of which only one eighth of the area needs to be modelled due to symmetry. The fractured EGS reservoir was modelled using the multiple interacting continua (MINC) conceptual model with fracture spacing of 10 m. Dry CO₂ was injected at the bottom of the initially brine-saturated reservoir and hot fluids were produced from the top of the reservoir. Simulations show that the brine contained in the fractures is produced initially, and only a few weeks later, the CO₂ plume breaks through at the production well. The two-phase nature of flow at this time causes a reduction in flow rate. Fluid production increases again as the reservoir dries out and the injected CO₂ fills the fractures (and more slowly the matrix). As the produced fluid becomes single-phase CO₂, energy production is enhanced. For salt mass fractions of the order of 0.01 (salinity of 10,000 ppm), total heat produced during the lifetime of the well (about 6 years) is 270% more than that achievable with H₂O as the working fluid. This result is probably at the lower end of what had been previously suggested. Simulation results show that as the brine is driven out of the matrix by capillary pressure, H₂O evaporates into the CO₂ plume and salt precipitates in the fractures clogging up the flow system. At the highest salt mass fraction modelled here (0.15), enhanced energy production is inhibited by halite precipitation in the fractures. The simulations suggest that for low-salinity systems, significant clogging occurs close to the production well after less than 10 years, while at high salinities clogging occurs close to the injection well in less than one year. Even though clogging of the reservoir is an apparently inevitable consequence of the drying of the saline geothermal reservoir, the fact that clogging occurs in specific reservoir regions could imply that remediation strategies could be developed to mitigate clogging.

13/01665 Operation strategy analysis of a geothermal step utilization heating system

Zheng, G. *et al. Energy*, 2012, 44, (1), 458–468.
Geothermal energy has been successfully applied in many district heating systems. In order to promote better use of geothermal energy, it is important to analyse the operation strategy of geothermal heating system. This study proposes a comprehensive and systematic operation strategy for a geothermal step utilization heating system (GSUHS). Calculation models of radiator heating system (RHS), radiant floor heating system (RFHS), heat pump (HP), gas boiler (GB), plate heat exchanger (PHE) and pump are first established. Then the operation strategy of the GSUHS is analysed with the aim to substantially reduce the conventional energy consumption of the whole system. Finally, the energy efficiency and geothermal tail water temperature are analysed. With the operation strategy in this study, the geothermal energy provides the main heating amount for the system. The heating seasonal performance factor is 15.93. Compared with coal-fired heating, 75.1%

of the standard coal equivalent can be saved. The results provide scientific guidance for the application of an operation strategy for a geothermal step utilization heating system.

13/01666 Performance evaluation under the actual operating condition of a vertical ground source heat pump system in a school building

Kim, E. *et al. Energy and Buildings*, 2012, 50, 1–6.

This study evaluates the performance of a ground source heat pump (GSHP) system installed in the Pusan National University, Korea. The GSHP system consists of ground heat exchanger (GHE), measuring devices and heat pumps which have two compressors (inverter type and fixed type). The closed vertical type GHE is constructed with 24 boreholes of 175 m in depth. The outdoor temperature, the indoor temperature and relative humidity, the inlet and outlet temperature of circulating water are measured. Also, the electricity consumption of compressor and cooling (heating) load are measured in order to analyse the coefficient of performance (COP) of the heat pump. From the measured data, the variation of ground temperatures at 2.5 and 5.0 m depth are affected by outdoor air temperature. But it is shown that ground temperature is almost constant below a depth of 10 m. In the cooling period, the COP of the heat pump is 6.0–10.9 at a partial load condition, while the overall system COP is 4.3–7.4. In the heating period, the COP of the heat pump is 4.3–8.3 at partial load condition, while the overall system COP is 3.0–6.2.

13/01667 Solar enhanced natural draft dry cooling tower for geothermal power applications

Zou, Z. *et al. Solar Energy*, 2012, 86, (9), 2686–2694.

This paper presents a new concept of hybrid cooling, named solar enhanced natural draft dry cooling tower (SENDDCT), in which solar collectors are added to traditional natural draft dry cooling towers to increase their performance. The purpose of using solar energy in this new cooling system is to increase the suction through the tower so that more air flow is achieved through the compact heat exchangers that cool condensers of a geothermal power plant. For the same size of the cooling tower, more air flow across the heat exchangers means more heat can be rejected by the system. The governing equations for the SENDDCT are similar to those of a conventional natural draft dry cooling tower except that solar heating is added after the heat exchanger bundles. Performance comparisons show that SENDDCT has substantial advantages over conventional natural draft dry cooling towers for geothermal power plants as well as standalone solar chimney power plants.

13/01668 Solute and geothermal flux monitoring using electrical conductivity in the Madison, Firehole, and Gibbon Rivers, Yellowstone National Park

McCleskey, R. B. *et al. Applied Geochemistry*, 2012, 27, (12), 2370–2381.

The thermal output from the Yellowstone magma chamber can be estimated from the Cl flux in the major rivers in Yellowstone National Park, USA; and by utilizing continuous discharge and electrical conductivity measurements the Cl flux can be calculated. The relationship between electrical conductivity and concentrations of Cl and other geothermal solutes (Na, SO₄, F, HCO₃, SiO₂, K, Li, B, and As) was quantified at monitoring sites along the Madison, Gibbon, and Firehole Rivers, which receive discharge from some of the largest and most active geothermal areas in Yellowstone. Except for some trace elements, most solutes behave conservatively and the ratios between geothermal solute concentrations are constant in the Madison, Gibbon, and Firehole Rivers. Hence, dissolved concentrations of Cl, Na, SO₄, F, HCO₃, SiO₂, K, Li, Ca, B and As correlate well with conductivity ($R^2 > 0.9$ for most solutes) and most exhibit linear trends. The 2011 flux for Cl, SO₄, F and HCO₃ determined using automated conductivity sensors and discharge data from nearby US Geological Survey gauging stations is in good agreement with those of previous years (1983–1994 and 1997–2008) at each of the monitoring sites. Continuous conductivity monitoring provides a cost- and labour-effective alternative to existing protocols whereby flux is estimated through manual collection of numerous water samples and subsequent chemical analysis. Electrical conductivity data also yield insights into a variety of topics of research interest at Yellowstone and elsewhere. (1) Geyser eruptions are easily identified and the solute flux quantified with conductivity data. (2) Short-term heavy rain events can produce conductivity anomalies due to dissolution of efflorescent salts that are temporarily trapped in and around geyser basins during low-flow periods. During a major rain event in October 2010, 180,000 kg of additional solute was measured in the Madison River. (3) The output of thermal water from the Gibbon River appears to have increased by about 0.2%/a in recent years, while the output of thermal water for the Firehole River shows a decrease of about 10% from 1983 to 2011. Confirmation of these trends will require continuing Cl flux monitoring over the coming decades.

13/01669 Thermal monitoring and optimization of geothermal district heating systems using artificial neural network: a case study

Keçebaş, A. and Yabanova, I. *Energy and Buildings*, 2012, 50, 339–346.

This paper deals with determining the energy and exergy efficiencies and exergy destructions for thermal optimization of a geothermal district heating system by using the artificial neural network (ANN) technique. As a comprehensive case study, the Afyonkarahisar geothermal district heating system (AGDHS) in Afyonkarahisar, Turkey is considered and its actual thermal data as of average weekly data are collected in heating seasons during the period 2006–2010 for ANN-based monitoring and thermal optimization. The measured data and calculated values are used at the design of Levenberg–Marquardt (LM) based multi-layer perceptron (MLP) in Matlab program. The results of the study are described graphically. The results show that the developed model is found to quickly predict the thermal performance and exergy destructions of the AGDHS with good accuracy. In addition, two main factors play important roles in the thermal optimization: (i) ambient temperature and (ii) flow rates in energy distribution cycle of the AGDHS. Various cases are investigated to determine how to change the energy and exergy efficiencies of the AGDHS for the temperature and flow rate. Finally, a monitoring and performance evaluation of a geothermal district heating system and its components by ANN will reduce the losses and human involvement and make the system more effective and efficient.

13/01670 Thermodynamic analysis of two micro CHP systems operating with geothermal and solar energy

Tempesti, D. *et al. Applied Energy*, 2012, 97, 609–617.

Micro combined heat and power (CHP) plants operating through an organic Rankine cycle (ORC) using renewable energy are analysed. The reference system is designed to produce 50 kW_e. The heat sources of the system are geothermal energy at low temperature (80–100 °C) and solar energy. Two different system layouts, a single and a double stage arrangement, are presented. The first uses a solar field composed only by evacuated solar collectors, and work is produced by a single turbine. In the double-stage system, a field of evacuated solar collectors heats the working fluid up to an intermediate temperature. After this first stage, only a part of the working fluid flow rate is heated in a second solar field, composed of direct-steam parabolic through collectors (PTCs), up to the maximum temperature of the cycle. The mechanical work is then produced in two turbo-expanders arranged in series. For the investigations, different working fluids (e.g. R134a, R236fa, R245fa) are considered. The results of the simulation in terms of efficiencies, heat and electricity production and the main characteristics of the system (i.e. heat exchanger surface, solar collector area) are presented and discussed.

13/01671 Vertical temperature profiles and borehole resistance in a U-tube borehole heat exchanger

Beier, R. A. *et al. Geothermics*, 2012, 44, 23–32.

The design of ground source heat pump systems requires values for the ground thermal conductivity and the borehole thermal resistance. *In situ* thermal response tests (TRT) are often performed on vertical boreholes to determine these parameters. Most TRT analysis methods apply the mean of the inlet and outlet temperatures of the circulating fluid along the entire borehole length. This assumption is convenient but not rigorous. To provide a more general approach, this paper develops an analytical model of the vertical temperature profile in the borehole during the late-time period of the *in situ* test. The model also includes the vertical temperature profile of the undisturbed ground. The model is verified with distributed temperature measurements along a vertical borehole using fibre optic cables inside a U-tube for the circulating fluid. The borehole thermal resistance is calculated without the need for the mean temperature approximation. In the studied borehole, the mean temperature approximation overestimates the borehole resistance by more than 20%.

Solar energy

13/01672 An integrated solar thermal power system using intercooled gas turbine and Kalina cycle

Peng, S. *et al. Energy*, 2012, 44, (1), 732–740.

A new solar tower thermal power system integrating the intercooled gas turbine top cycle and the Kalina bottoming cycle is proposed in the present paper. The thermodynamic performance of the proposed system is investigated, and the irreversibility of energy conversion is disclosed using the energy–utilization diagram method. On the top cycle of the proposed system, the compressed air after being intercooled is heated at 1000 °C or higher at the solar tower receiver and is used to drive the gas turbine to generate power. The ammonia–

water mixture as the working substance of the bottom cycle recovers the waste heat from the gas turbine to generate power. A concise analytical formula of solar-to-electric efficiency of the proposed system is developed. As a result, the peak solar-to-electric efficiency of the proposed system is 27.5% at a gas turbine inlet temperature of 1000 °C under the designed solar direct normal irradiance of 800 W/m². Compared with a conventional solar power tower plant, the proposed integrated system conserves approximately 69% of consumed water. The results obtained in the current study provide an approach to improve solar-to-electric efficiency and offer a potential to conserve water for solar thermal power plants in arid area.

13/01673 Assessment of forecasting techniques for solar power production with no exogenous inputs

Pedro, H. T. C. and Coimbra, C. F. M. *Solar Energy*, 2012, 86, (7), 2017–2028.

This study evaluates and compares several forecasting techniques using no exogenous inputs for predicting the solar power output of a 1 MWp, single-axis tracking, photovoltaic power plant operating in Merced, California, USA. The production data used in this work correspond to hourly averaged power collected from November 2009 to August 2011. Data prior to January 2011 are used to train the several forecasting models for the 1 and 2 h ahead hourly averaged power output. The methods studied in this work are: persistent model, auto-regressive integrated moving average, k-nearest-neighbours, artificial neural networks (ANNs), and ANNs optimized by genetic algorithms (GA). The accuracy of the models is determined by computing error statistics such as mean absolute error, mean bias error, and the coefficient of correlation (R^2) for the differences between the forecasted values and the measured values for the period from January to August of 2011. This work also addresses the accuracy of the different methods as a function of the variability of the power output, which depends strongly on seasonal conditions. The findings show that the ANN-based forecasting models perform better than the other forecasting techniques, that substantial improvements can be achieved with a GA optimization of the ANN parameters, and that the accuracy of all models depends strongly on seasonal characteristics of solar variability.

13/01674 Building a bankable solar radiation dataset

Vignola, F. *et al. Solar Energy*, 2012, 86, (8), 2218–2229.

A robust solar radiation dataset is essential for securing competitive financing for solar power projects. The majority of solar radiation datasets are derived from publically available data, though there are an increasing number of proprietary datasets being developed and marketed. Most of these new datasets represent models based on satellite images and validated with ground measured data. This paper focuses on the strengths and weaknesses of the existing publically available solar radiation databases, though the commentary is equally relevant to the newer commercial datasets. While the financing community generally views the solar resource as stable, it also views the material miscalculation of the solar resource as one of the biggest risks in a solar project. Therefore, lenders and rating agencies alike require verification of the solar resource dataset to be utilized at each project location as this translates directly into electric energy production forecasts and revenues. The variability of the solar resource as exhibited by the historical solar data and the accuracy of the dataset play significant roles in estimating the probability of future performance and influences the financial contract that the project is likely to receive.

13/01675 Calculating the diffuse solar radiation in regions without solar radiation measurements

Li, H. *et al. Energy*, 2012, 44, (1), 611–615.

Correlations for calculating diffuse solar radiation can be classified into models with global solar radiation (H -based method) and without it (Non- H method). The objective of the present study is to compare the performance of H -based and Non- H methods for calculating the diffuse solar radiation in regions without solar radiation measurements. The comparison is carried out at eight meteorological stations in China focusing on the monthly average daily diffuse solar radiation. Based on statistical error tests, the results show that the Non- H method that includes other readily available meteorological elements gives better estimates. Therefore, it can be concluded that the Non- H method is more appropriate than the H -based one for calculating the diffuse solar radiation in regions without solar radiation measurements.

13/01676 Energy and exergy analysis of a building integrated semitransparent photovoltaic thermal (BISPVT) system

Vats, K. and Tiwari, G. N. *Applied Energy*, 2012, 96, 409–416.

In this paper, a study has been carried out to evaluate the energy and exergy performance of a building integrated semitransparent photovoltaic thermal (BISPVT) system integrated to the roof of a room. Comparisons have been carried out on the basis of energy and exergy by considering six different photovoltaic (PV) modules. It is observed

that maximum annual electrical energy is 810 kWh for heterojunction comprised of a thin amorphous silicon (a-Si) PV cell on top of a crystalline silicon (c-Si) cell (also known as HIT) and the maximum annual thermal energy is 464 kWh for a-Si. It is also concluded that HIT PV module is suitable for producing electrical power whereas a-Si is suitable for space heating. However, an annual overall thermal energy (2497 kWh) and exergy (834 kWh) is maximum for HIT PV module.

13/01677 Exergetic optimization for solar heat receiver with heat loss and viscous dissipation

Lu, J. *et al. Solar Energy*, 2012, 86, (9), 2273–2281.

The exergetic efficiency of heat receiver in solar thermal power system is optimized by considering the heat loss outside the receiver and fluid viscous dissipation inside the receiver. The physical models of heat loss and pumping power consumption for solar heat receiver are first proposed, and associated exergetic efficiency is further induced. As the flow velocity rises, the pumping power consumption and heat absorption efficiency significantly rises, and the maximum absorption efficiency and optimal incident energy flux also increase. Along the flow direction of solar receiver, the exergy flux increment and the flow exergy loss almost linearly increase, while the exergetic efficiency varies very slowly at high flow velocity. According to the exergetic efficiency loss from flow viscous dissipation, the exergetic efficiency of solar heat receiver will first increase and then decrease with the flow velocity. Because of the coupling effects of heat absorption efficiency and exergetic efficiency from fluid internal energy, the exergetic efficiency of solar heat receiver will approach to the maximum at proper inlet temperature. As a result, the exergetic efficiency of solar heat receiver will reach the maximum at optimal inlet temperature, incident energy flux and flow velocity.

13/01678 Experimental analysis of a solar PV/diesel hybrid system without storage: focus on its dynamic behavior

Yamegueu, D. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 267–274.

Integration of solar photovoltaic (PV) systems with diesel generators for the electrification of remote and rural areas would assist in expanding the electricity access in the sub-Saharan Africa region. In fact, countries of this region are well endowed in solar resource: their mean daily solar radiation exceeds 5.5 kWh/m²/day. They are, therefore, good locations for PV systems. This paper deals with an experimental study of the dynamic behaviour of a hybrid system prototype (based on 'flexy-energy' concept) set up at Kamboinsé, located 15 km from Ouagadougou (12.22°N and 1.31°W) in Burkina Faso. The prototype is composed of a 2.85 kWp PV array, a 3.3 kW single-phase inverter and a diesel generator rated at 9.2 kW. Two resistive load banks of about 4 kW each are used to simulate the load profiles. Experimental results show that the PV generation leads the distribution feeder to shift toward higher voltages. The voltage rise is exacerbated when the PV generation is at its highest and the demand at its lowest. Care should then be taken to ensure that for a hybrid PV/diesel system, the PV rated power connected to each phase of the diesel generator is as equal as possible. The present study also points out that 'well-designed' inverters generate very small voltage harmonics and current distortions, even when high PV penetration systems are considered.

13/01679 Impact of isoelectric points of nanopowders in electrolytes on electrochemical characteristics of dye sensitized solar cells

Mohanty, S. P. and Bhargava, P. *Journal of Power Sources*, 2012, 218, 174–180.

Nanoparticle loaded quasi solid electrolytes are important from the view point of developing electrolytes for dye sensitized solar cells (DSSCs) having long term stability. The present work shows the influence of isoelectric point of nanopowders in electrolyte on the photoelectrochemical characteristics of DSSCs. Electrolytes with nanopowders of silica, alumina and magnesia which have widely differing isoelectric points are used in the study. Adsorption of ions from the electrolyte on the nanopowder surface, characterized by zeta potential measurement, show that cations get adsorbed on silica, alumina surface while anions get adsorbed on magnesia surface. The electrochemical characteristics of nanoparticulate loaded electrolytes are examined through cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS). DSSCs fabricated using liquid, silica or alumina loaded electrolytes exhibit almost similar performance. But interestingly, the magnesia loaded electrolyte-based cell show lower short circuit current density (J_{sc}) and much higher open circuit voltage (V_{oc}), which is attributed to adsorption of anions. Such anionic adsorption prevents the dark reaction in magnesia loaded electrolyte-based cell and thus, enhances the V_{oc} by almost 100 mV as compared to liquid electrolyte based cell. Also, higher electron life time at the titania/electrolyte interface is observed in magnesia loaded electrolyte-based cell as compared to others.

13/01680 Integration between a thermophotovoltaic generator and an organic Rankine cycleDe Pascale, A. *et al. Applied Energy*, 2012, 97, 695–703.

The constant increase in energy need and the growing attention to the related environmental impact have given a boost to the development of new strategies in order to reduce the primary energy consumption and to improve its utilization. One of the possible strategies for achieving this aim is combined heat and power (CHP), especially if coupled with the concept of on-site generation (also known as distributed generation). These approaches allow the reduction of fuel consumption and pollutant emissions and the increase of security in energy supply. This paper introduces the thermophotovoltaic organic Rankine cycle (ORC) integrated system, an energy system integrating a thermophotovoltaic generator (TPV) and an ORC. This study represents the start-up of a research programme which involves three research teams from Italy. The aim of this research is the complete definition and the pre-prototyping characterization of this system covering all the unresolved issues in this field. More specifically, TPV is a system to convert the radiation emitted from an artificial heat source (i.e. the combustion of fuel) into electrical energy by the use of photovoltaic cells. In this system, the produced electrical power is strictly connected to the thermal one as their ratio is almost constant and cannot be changed without severe loss in performance. The coupling between TPV and ORC allows this limitation to be overcome by the realization of a CHP system which can be regulated with a large degree of freedom changing the ratio between the produced electrical and thermal power. In this study a thermodynamic analysis of this system is presented and discussed in order to highlight its potential in the distributed generation scenario.

13/01681 Intelligent maximum power point tracking for PV system using Hopfield neural network optimized fuzzy logic controllerSubiyanto, S. *et al. Energy and Buildings*, 2012, 51, 29–38.

This paper presents a new method for maximum power point tracking of photovoltaic (PV) energy harvesting system by using the Hopfield neural network (HNN) optimized fuzzy logic controller (FLC). In the proposed method, HNN is utilized to automatically tune the FLC membership functions instead of adopting the trial-and-error approach. A complete simulation model of a PV system using the MATLAB/Simulink software is developed to validate the HNN optimized FLC. A hardware prototype of the PV maximum power point tracking controller was also implemented using the dSPACE DS1104 controller. Simulation and experimental results show the performance and effectiveness of the HNN optimized FLC. It is proven that the proposed HNN optimized FLC can provide accurate tracking of the PV maximum power point and improve the efficiency of PV systems.

13/01682 Investigation on feasibility of ionic liquids used in solar liquid desiccant air conditioning systemLuo, Y. *et al. Solar Energy*, 2012, 86, (9), 2718–2724.

The corrosion problem of traditional liquid desiccants hinders the development of solar liquid desiccant air conditioning system. Ionic liquids (ILs) could be a possible substitute because of their low corrosion to metals. According to the characteristic of cation and anion, two ILs 1-butyl-3-methylimidazolium tetrafluoroborate ([Bmim]BF₄) and 1,3-dimethylimidazolium acetate ([Dmim]OAc) were selected for possibility investigation. The experimental results demonstrated that the surface vapour pressure of [Bmim]BF₄ aqueous solution was so high that it was not suitable for dehumidification. With comparing the structure of [Bmim]BF₄ and 1-ethyl-3-methylimidazolium tetrafluoroborate ([Emim]BF₄), it was found that for imidazole salts with the same anion, as the alkyl chain of the cation becomes shorter, the surface vapour pressure of its aqueous solution would be lower. In addition, simulation model was used to compare the dehumidification performance of [Dmim]OAc and [Emim]BF₄ with that of the traditional desiccants lithium Chloride (LiCl) and lithium bromide (LiBr). The results showed that in the same condition, [Dmim]OAc with an inlet mass concentration of 81.7% and [Emim]BF₄ of 85.5% could reach the same dehumidification rate as LiCl of 40.9% and LiBr of 45.0% mass concentration. Better dehumidification performance of [Dmim]OAc than that of [Emim]BF₄ was achieved, thus, like [Emim]BF₄, [Dmim]OAc can also be a promising substitute for traditional desiccant.

13/01683 Material constraints for concentrating solar thermal powerPihl, E. *et al. Energy*, 2012, 44, (1), 944–954.

Scaling up alternative energy systems to replace fossil fuels is a critical imperative. Concentrating solar power (CSP) is a promising solar energy technology that is growing steadily in a so far small, but commercial scale. Previous life cycle assessments have resulted in confirmation of low environmental impact and high lifetime energy return. This work contributes an assessment of potential material

restrictions for a large-scale application of CSP technology using data from an existing parabolic trough plant and one prospective state-of-the-art central tower plant. The material needs for these two CSP designs are calculated, along with the resulting demand for a high adoption (up to about 8000 TWh/yr by 2050) scenario. In general, most of the materials needed for CSP are commonplace. Some CSP material needs could however become significant compared to global production. The need for nitrate salts (NaNO₃ and KNO₃), silver and steel alloys (Nb, Ni and Mo) in particular would be significant if CSP grows to be a major global electricity supply. The possibilities for increased extraction of these materials or substituting them in CSP design, although at a marginal cost, mean that fears of material restriction are likely unfounded.

13/01684 Maximum power point tracking of partially shaded solar PV system using modified Fibonacci search method with fuzzy controllerRamaprabha, R. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 754–765.

This paper presents the modified Fibonacci search-based maximum power point tracking (MPPT) scheme for a solar photovoltaic array (SPVA) under partial shaded conditions. Partial shaded SPV modules produce several local maximum power points, which makes the tracking of the global maximum power a difficult task. Most of conventional tracking methods fail to work properly under these non-uniform insolation conditions. The real Fibonacci search based MPPT fails to track the global peak (GP) under partial shaded conditions. This paper improves the method by considering power ripple and wide search range so that the proposed method tracks GP for all the conditions. It is checked for different shading patterns through simulation and verified experimentally. In this paper, the advantage of using fuzzy logic controller (FLC) is also presented. Fuzzy rules are optimized using genetic algorithm (GA). Comparative studies have been made for Proportional plus Integral (PI), non-optimized FLC and GA optimized FLC. From the simulation results, it is observed that the fuzzy controller reduces error and it gives rapid response to environmental changes. Furthermore, it does not require any tuning of the parameters, unlike conventional PI controller, wherein the controller gain parameters needs to be changed when solar insolation changes.

13/01685 Microcontroller and solar power based electrical energy management system for renewable energy applicationsGhodki, M. K. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 852–860.

The microcontroller and solar power based electrical energy management system for renewable energy applications has its own distribution, controlling and monitoring system for the amount of electrical energy (kWh) and this system is based on smart energy metering. This hardware project measures the electrical energy (kWh) as well as controls the amount of electrical energy from supply to load during day and night automatically. It is also equipped with the control of alternative source of electricity (solar energy). The measurement can be performed up to 10 lac units and controlling can be up to two lac units. In the controlling part, the mains supply is automatically tripped and the project provides the alternative power supply in the absence of the mains supply by using the renewable (solar) energy source, when the energy consumption from the mains supply exceeds the preset limit.

13/01686 Modelling the heat dynamics of a monitored test reference environment for building integrated photovoltaic systems using stochastic differential equationsLodi, C. *et al. Energy and Buildings*, 2012, 50, 273–281.

This paper deals with grey-box modelling of the energy transfer of a double skin building integrated photovoltaic (BIPV) system. Grey-box models are based on a combination of prior physical knowledge and statistics, which enable identification of the unknown parameters in the system and accurate prediction of the most influential variables. The experimental data originates from tests carried out with an air-based BIPV system installed in a test reference environment. BIPV systems represent an interesting application for achieving the requirements of the European Union's Energy Performance of Buildings Directive. Indeed, these systems could reduce the ventilation thermal losses of the building by pre-heating the fresh air. Furthermore, by decreasing photovoltaic (PV) module temperature, the ventilation air heat extraction can simultaneously increase electrical and thermal energy production of the building. A correct prediction of the PV module temperature and heat transfer coefficients is fundamental in order to improve the thermo-electrical production. The considered grey-box models are composed of a set of continuous time stochastic differential equations, holding the physical description of the system, combined with a set of discrete time measurement equations, which represent the

data driven part. In the present work, both one-state and two-state non-linear grey-box models are considered. In order to validate the results, the residuals are analysed for white-noise properties.

13/01687 Optimum PV-diesel hybrid systems for remote consumers of the Greek territory

Kaldellis, J. *et al. Applied Energy*, 2012, 97, 61–67.

On the numerous small and medium-sized Greek islands one may encounter several thousands of remote consumers unable to appreciate a direct electricity utility supply. For this purpose, remote consumers usually cover their electricity needs based on the operation of small diesel-generator sets. On the other hand, most of these areas appreciate high quality solar potential that comprises a stimulus for the use of stand-alone photovoltaic (PV)-based configurations. In this context, the primary objective of the present study is to determine the optimum dimensions of a stand-alone PV-diesel system, under the restriction of minimum long-term electricity generation cost, and accordingly obtain a comparison with diesel-only systems. For this purpose, the developed methodology is applied to a representative Greek island, with results obtained being rather encouraging for the implementation of the proposed solution.

13/01688 Parametric sensitivity analysis of a SOLRGT system with the indirect upgrading of low/mid-temperature solar heat

Li, Y. Y. *et al. Applied Energy*, 2012, 97, 648–655.

Development of novel solar-fossil fuel hybrid system is important for the efficient utilization of low temperature solar heat. A solar-assisted methane chemically recuperated gas turbine (SOLRGT) system has been proposed which integrated solar heat into a high-efficiency power system. The low-temperature solar heat is first converted into vapour latent heat provided for a reformer, and then indirectly upgraded to high-grade generated syngas chemical energy by the reformation reaction. In this paper, based on the above mentioned cycle, a parametric analysis is performed using ASPEN PLUS code to further evaluate the effect of key thermodynamics parameters on the SOLRGT performance. It can be shown that solar collector temperature, steam/air mass ratio, turbine inlet pressure, and turbine inlet temperature have significant effects on system efficiency, solar-to-electricity efficiency, fossil fuel saving ratio, specific CO₂ emission and so on. The solar collector temperature is varied between 140 and 240 °C and the maximum net solar-to-electricity efficiency and system efficiency for a given turbine inlet condition (turbine inlet temperature of 1308 °C and pressure ratio of 15) is 30.2% and 52.9%, respectively. The fossil fuel saving ratio can reach up to 21.8% and the reduction of specific CO₂ emission is also 21.8% compared to the reference system. The system performance is promising for an optimum pressure ratio at a given turbine inlet temperature.

13/01689 Research on an adsorption cooling system supplied by solar energy

Sekret, R. and Turski, M. *Energy and Buildings*, 2012, 51, 15–20.

In the current article, research on the possibilities for ensuring thermal comfort through the use of an adsorption cooling system supplied by solar energy is presented. The main goal was to ensure an adequate level of cooling in a referential room of 40 m³ in volume. Cooling was attained by an adsorption ice water generator (AIWG) that was supplied by energy from flat-plate solar collectors. Experiments on the AIWG working conditions and an analysis of the possibilities for using solar energy in a region of Czeszochowa in Poland to supply an adsorption cooling system are also presented. The real value of the cooling efficiency of the coefficient of performance for the adsorption ice water generator was 0.27, and the real global efficiency of the adsorption cooling system was 0.23. On the basis of the results, it was assumed that, in climate conditions typical for Poland, it is possible to effectively use the adsorption cooling system to keep a constant level of thermal comfort during all months in which there is a demand for cooling, i.e. between April and October.

13/01690 Simulation of the parabolic trough solar energy generation system with organic Rankine cycle

He, Y.-L. *et al. Applied Energy*, 2012, 97, 630–641.

A model for a typical parabolic trough solar thermal power generation system with organic Rankine cycle (PT-SEGS-ORC) was built within the transient energy simulation package TRNSYS, which is formed by integrating several submodels for the trough collector system, the single-tank thermal storage system, the auxiliary power system and the heat-electricity conversion system. With this model, the effects of several key parameters, including the interlayer pressure between the absorber tube and the glass tube (p_{inter}), the flow rate of high temperature oil in the absorber tube ($\dot{v}$), solar radiation intensity (I_{dn}) and incidence angle (θ), on the performance of the parabolic trough collector field based on the meteorological data of Xi'an city were examined. The study shows that the heat loss of the solar collector (q_{loss}) increases sharply with the increase in p_{inter} at beginning and then

reaches to an approximately constant value. The variation of heat collecting efficiency (η_{hc}) with $\dot{v}$ is quite similar to the variation of q_{loss} with p_{inter} . However, I_{dn} and θ exhibit opposite effect on η_{hc} . In addition, it is found that the optimal volume of the thermal storage system is sensitively dependent on the solar radiation intensity. The optimal volumes are 100, 150, 50, and 0 m³ for spring equinox, summer solstice, autumnal equinox and winter solstice, respectively.

13/01691 Solar load ratio and ISO 13790 methodologies: indirect gains from sunspaces

Panão, M. J. N. O. *et al. Energy and Buildings*, 2012, 51, 212–222.

This paper reviews and analyses the compatibility of the simplified empirical method based on the dimensionless parameter of solar load ratio (SLR) and the monthly procedure of the standard ISO 13790 for indirect gains, specifically for unconditioned zones adjacent to a conditioned zone, but separated from it by a partition wall (sunspaces). The main contribution of the work presented here is the new formulation to account SLR correlations in ISO 13790, obtained for sunspaces, but generalizable for other solar systems with known SLR functions. Simulation models are used to perform a sensitivity analysis of internal gains and heat transfer through solar collector surfaces, both issues that distinguishes ISO 13790 from load ratio methods. The analysis shows that internal gains can be added to the heat source term or subtracted to heat transfer term without influencing the utilization factor dependence with the gain-to-loss ratio. On the other hand, the SLR assumption that solar collector surfaces are neutral elements and, therefore, not added to the heat transfer term, results in large inconsistencies between SLR and ISO 13790 methods. The detailed monthly methodology of ISO 13790 fairly reproduces results obtained by simulation. However, predictions from the simplified monthly methodology of ISO 13790 fail in mid-season months and the coldest months.

13/01692 Suitability of coupling a solar powered ejection cycle with a vapour compression refrigerating machine

Chesi, A. *et al. Applied Energy*, 2012, 97, 374–383.

The most commonly employed technology for cold production is vapour compression, mainly due to the high efficiency of such devices. However, a major operating issue is the strong dependency of system efficiency and capacity on ambient temperature, which in turn leads to low yearly performance and to a low capacity factor. On the other hand, solar cooling is gaining an increasing appeal as a way to locally exploit renewable energy sources and reducing carbon footprint. Many thermally driven systems are being currently studied, among these the ejection reverse cycle is being proposed as an interesting alternative due to its simplicity, low cost and reliability. The present paper aims to analyse a complex system in which the solar powered ejection machine is used to increase the efficiency of a traditional vapour compression machine by subtracting heat from the condenser. By means of a transient analysis, performed with a reference building and with climate data corresponding to four different system locations worldwide, the year-round performance of such a system in a space cooling application is estimated in terms of energy balance and savings on power costs with respect to the traditional solutions, in order to evaluate its potential benefits and to highlight some issues related to system design and operation. A sensitivity analysis is also performed with respect to solar collector area and equipment sizing, showing how the latter is an important optimization parameter when designing the system.

13/01693 The impact of state financial incentives on market deployment of solar technology

Sarzynski, A. *et al. Energy Policy*, 2012, 46, 550–557.

Many states have adopted financial incentives to encourage market deployment of solar energy technology. This paper employs a cross-sectional time-series approach to evaluate the extent to which state solar financial incentives systematically encouraged market deployment of solar photovoltaic (PV) technology from 1997 to 2009. The results demonstrate that states offering cash incentives such as rebates and grants experienced more extensive and rapid deployment of grid-tied PV technology than states without cash incentives over the study period. The analysis also finds that the presence of state renewable energy portfolio standards and specific solar carve-out provisions within them heavily influenced the market deployment of grid-tied solar PV technology through 2009.

13/01694 The potential of building-integrated (BIPV) and building-applied photovoltaics (BAPV) in single-family, urban residences at low latitudes in Brazil

dos Santos, Í. P. and Rütther, R. *Energy and Buildings*, 2012, 50, 290–297.

The integration of solar modules on buildings' roofs and façades is one of the most elegant applications of photovoltaics (PV). With the declining costs of this technology, building-integrated and building-applied PVs (BIPV and BAPV) can efficiently and cost-competitively

assist in delivering electricity in urban environments. The authors have quantified the potential of BIPV and BAPV generators on existing single-family detached residential buildings in Florianopolis, Brazil (latitude 27°S, solar irradiation 1550 kWh/m²/year), in supplying each house and a fraction of the local utility feeder's electricity demands. They have measured and compared the annual output performance of thin-film amorphous silicon, and traditional crystalline silicon solar PV technologies, and proposed solar PV kits to be installed on all of the existing 496 residential buildings roof tops in the mixed residential-commercial area studied. The typical single-family, detached home roof covers can easily accommodate the proposed PV kits, with 87% of these generators yielding at least 95% of the maximum theoretical generation output of an ideally oriented and tilted PV system. Low-pitched, existing roof covers in residential houses represent excellent areas for PV integration at low latitudes. Installing BIPV on all of the available roof areas can make each and every house a net energy-positive building.

13/01695 The relation of collector and storage tank size in solar heating systems

Çomaklı, K. *et al. Energy Conversion and Management*, 2012, 63, 112–117.

The most popular method to benefit from the solar energy is to use solar water heating systems since it is one of the cheapest way to benefit from the solar energy. The investment cost of a solar water heating system is very low, and the maintenance costs are nearly zero. Using the solar energy for solar water heating (SWH) technology has been greatly improved during the past century. A storage tank is used in many solar water heating systems for the conservation of heat energy or hot water for use when some need it. In addition, domestic hot water consumption is strongly variable in many buildings. It depends on the geographical situation, also on the country customs, and of course on the type of building usage. Above all, it depends on the inhabitants' specific lifestyle. For that reason, to provide the hot water for consumption at the desirable temperature whenever inhabitants require it, there must be a good relevance between the collectors and storage tank. In this paper, the optimum sizes of the collectors and the storage tank are determined to design more economic and efficient solar water heating systems. A program has been developed and validated with the experimental study and environmental data. The environmental data were obtained through a whole year of operation for Erzurum, Turkey.

13/01696 Theoretical model and experimental validation of a direct-expansion solar assisted heat pump for domestic hot water applications

Moreno-Rodríguez, A. *et al. Energy*, 2012, 45, (1), 704–715.

This paper has shown the development of a theoretical model to determine the operating parameters and consumption of a domestic hot water (DHW) installation, which uses a direct-expansion solar assisted heat pump (DXSAHP) with refrigerant R-134a, a compressor with a rated capacity of 1.1 kW and collectors with a total area of 5.6 m². The model results have been compared and validated the experimental results obtained with the equipment installed at the University Carlos III, south of Madrid, Spain. The analysis was conducted over the course of a year, and the results have been represented depending on the meteorological and process variables of several representative days. Taking into account the thermal losses of the installation and the dependency on the operating conditions, the acquired experimental coefficient of performance is between 1.7 and 2.9, while the DHW tank temperature over the course of the study is 51 °C.

13/01697 Thermoeconomic analysis of a solar enhanced energy storage concept based on thermodynamic cycles

Henchoz, S. *et al. Energy*, 2012, 45, (1), 358–365.

Large-scale energy storage may play an increasingly important role in the power generation and distribution sector, especially when large shares of renewable energies will have to be integrated into the electrical grid. Pumped-hydro is the only large-scale storage technology that has been widely used. However the spread of this technology is limited by geographic constraints. In the present work, a particular implementation of a storage concept based on thermodynamic cycles, invented by ABB Switzerland Ltd. Corporate research, has been analysed thermoeconomically. A variant using solar thermal collectors is presented. It benefits from the synergy between daily variations in solar irradiance and in electricity demand. This results in an effective increase of the electric energy storage efficiency. A steady state multi-objective optimization of a 50 MW plant was done; minimizing the investment costs and maximizing the energy storage efficiency. Several types of cold storage substances have been implemented in the formulation and two different types of solar collector were investigated. A storage efficiency of 57% at a cost of US\$1200/kW was

calculated for an optimized plant using solar energy. Finally, a computation of the behaviour of the plant along the year showed a yearly availability of 84.4%.

13/01698 Thin ZnO nanocrystalline films for efficient quasi-solid state electrolyte quantum dot sensitized solar cells

Karageorgopoulos, D. *et al. Journal of Power Sources*, 2012, 219, 9–15. Thin transparent ZnO nanocrystalline films are prepared through a novel facile method based on an amino double-edged polypropylene oligomer and zinc precursor. While amines were reacted with acetate groups of zinc acetate starting material, the polypropylene oligomers acted as template for the oxide formation. Different structural properties of the ZnO films were achieved varying the quantity of the oligomer in the starting solution. Spherical aggregated or monodispersed particles were formed with average sizes ranging from 10 to 30 nm. The films were employed in the construction of quantum dot sensitized solar cells using both CdS and CdSe. For first time a quasi-solid state electrolyte was applied succeeding a maximum overall efficiency of 4.5% in the case of aggregated particles which could probably act as scattering centres. The quasi solid state electrolyte was a hybrid organic-inorganic material with SiO₂ edged groups while no water was used in any step of preparation of the host electrolyte for a polysulfide redox couple.

13/01699 Towards the establishment of maximum PV generation limits due to power quality constraints

Patsalides, M. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 285–298.

The solar irradiance dependent level of harmonic distortion due to photovoltaic (PV) generation is investigated through a combination of experimental and simulation studies. The expected growth of connection densities of PV systems in distribution networks coupled to the environmental conditions and in particular the fluctuations in solar irradiance can lead to undesirable variations of power and supply quality. In order to be able to predict the harmonic pollution due to PV generation, measurements of power quality indices were carried out at the output of a PV system for a period of 2 weeks. Then, a typical distribution system was modelled using the statistically obtained outcome of the measurements from the PV system. From the simulation of the chosen distribution system, results were obtained for voltage distortion and categorized them based on solar irradiance levels. The procedure was then validated using the EN 50160 analysis approach. The most extreme case, the high solar irradiance condition, was subsequently used for the simulation of different concentration scenarios, in order to assess the concentration limits set by power quality indices and the results are presented. The measurement-based analysis presented, identifies that with current inverters, maximum permissible concentrations of PV can be reached under certain circumstances. From this work, it has been observed that in the main the levels of power quality of busbars inside a distribution network decrease by installing higher concentrations of PV systems. Further research is necessary to establish effective guidelines for the proper installation of grid connected photovoltaic systems in distribution networks. Additionally, proper planning is required which should also consider means of harmonic compensation and filtering.

13/01700 Two kinds of graphene-based composites for photoanode applying in dye-sensitized solar cell

Tang, B. and Hu, G. *Journal of Power Sources*, 2012, 220, 95–102.

Two kinds of graphene modified TiO₂ composites are synthesized by hydrothermal method and layer-by-layer self-assembly technology. Graphene/titanate nanotubes (GTNTs) films have great light-harvesting efficiencies, and the amount of graphene does not obviously influence their optical performance. Alternating graphene/TiO₂ (prepared by supercritical treatment, GSCT) multilayer films possess superior electron transport ability, and the number of bi-layers plays as a central role for their electrical property. The outstanding light scattering and carrier transport properties of these promising films promote the performance of dye-sensitized solar cells (DSSCs). The power conversion efficiencies (η) of the DSSCs reach 6.46% and 7.54% under AM-1.5G by using GSCT-P25 (10 μ m) and P25-GTNTs (15 μ m) photoanodes, and the increases are 33.8% and 20.6% compared with that of by using a P25 photoanode with same thickness. The η reaches 8.67% when a preliminarily optimized GSCT-P25-GTNTs (15 μ m) photoanode is adopted, which is far better than employing a pure P25 photoanode (6.25%).

Wind energy

13/01701 A mean flow acoustic engine capable of wind energy harvesting

Sun, D. *et al. Energy Conversion and Management*, 2012, 63, 101–105. Based on the mean flow induced acoustic oscillation effect, a mean flow acoustic engine (MFAE) converts wind energy and fluid energy in pipeline into acoustic energy which can be used to drive thermoacoustic refrigerators and generators without any mechanical moving parts. With natural wind simulated by a centrifugal air fan, a MFAE with a cross-junction configuration was designed and manufactured for experimental study. Stable standing wave acoustic fields were established in specific ranges of air flow velocity. Experimental and computational results reveal the acoustic field distribution in the engine and show the effect of the mean flow velocity and the Strouhal number on the acoustic field characteristics. With a mean flow velocity of 50.52 m/s and a mean pressure of 106.19 kPa, the maximum pressure amplitude of 6.20 kPa was achieved, which was about 5.8% of the mean pressure. It has laid a good foundation for driving power generation devices and thermoacoustic refrigerators by a MFAE.

13/01702 A multi-terminal HVDC transmission system for offshore wind farms with induction generators

Liang, J. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 54–62.

Voltage source converter, multi-terminal high-voltage direct current (HVDC) transmission (MTDC) for the connection of large offshore wind farms to the terrestrial grid is investigated. Induction generators without the need of wind turbine converters are installed in the wind farms due to the supports from the voltage source converters of the HVDC. A control system is designed which incorporates the voltage–current characteristics of the voltage source converters and the power reduction from the wind turbines during a fault. During normal operation, grid side converters control the DC voltage and coordinate the power sharing to the terrestrial grids. During abnormal operation, wind farm side converters take over the DC voltage control and coordinate the power reduction between wind farms. The control system removes the requirement for fast communication between the converters and achieves automatic coordination. The dynamic performance of a MTDC with the control system is tested through simulations using PSCAD/EMTDC.

13/01703 A short overview on purification and conditioning of syngas produced by biomass gasification: catalytic strategies, process intensification and new concepts

Richardson, Y. *et al. Progress in Energy and Combustion Science*, 2012, 38, (6), 765–781.

Application of the process intensification concept to biomass gasification is relatively recent, but is arousing growing interest by providing true opportunities for developing cost-effective high quality syngas, particularly for small to medium-scale installations, adapted to the economic context of most regions in the world. In this highly swarming context towards process intensification, this article provides an overview of the different strategies which are reported in the literature to perform syngas or H_2 purification and conditioning into the gasifier. A promising avenue towards process intensification consists in integrating several functionalities into suitable fluidized bed gasifiers, such as catalytic tar cracking/reforming, CO_2 elimination, H_2 separation and the elimination of particles and other contaminants. The development of new catalytic integrated gasification concepts is also proposed to achieve high conversion performances while pursuing significant process intensification. This strategy is illustrated by relevant examples such as the design of short contact time partial oxidation catalytic reactors, the implementation of specific reaction media such as supercritical water or molten metal, or the realization of a close contact between solid catalysts and lignocellulosic biomass. Most of these different technologies are not mature yet and research effort has to be performed for optimizing each of these approaches, calling for a multidisciplinary and multi-scale approach integrating catalysis, chemistry, reaction and process engineering. The design of new advanced gasification reactor concept still has to be pursued in order to achieve the challenging one-step production of a high quality syngas from biomass gasification. The implementation of such innovative biomass gasification breakthrough concepts could be one of the most promising ways of process intensification resulting in a significant cut down of the production costs of synthesis gas and H_2 derived from biomass.

13/01704 Aerodynamic design of a 300 kW horizontal axis wind turbine for province of Semnan

Sedaghat, A. and Mirhosseini, M. *Energy Conversion and Management*, 2012, 63, 87–94.

In this research, blade element momentum theory (BEM) is used to design a HAWT blade for a 300 kW horizontal axis wind turbine. The airfoil is RISØ-A1–18, produced by RISØ National Laboratory, Denmark. Desirable properties of this airfoil are related to enhancement of aerodynamic and structure interactions. Design parameters considered here are wind tip speed ratio, nominal wind speed and diameter of rotor. The nominal wind speed was obtained from statistical analysis of wind speed data from province of Semnan in Iran. BEM is used for obtaining maximum lift to drag ratio for each elemental constitution of the blade. Obtaining chord and twist distribution at assumed tip speed ratio of blade, the aerodynamic shape of the blade in every part is specified which correspond to maximum accessible power coefficient. The design parameters are trust coefficients, power coefficient, angle of attack, angle of relative wind, drag and lift coefficients, axial and angular induction factors. The blade design distributions are presented versus rotor radius for BEM results. The blade shape then can be modified for ease of manufacturing, structural concerns, and to reduce costs.

13/01705 Analysing the determinants of on-shore wind capacity additions in the EU: an econometric study

del Río, P. and Tarancón, M.-A. *Applied Energy*, 2012, 95, 12–21.

The aim of this paper is to identify the determinants of differences in on-shore wind electricity capacity additions in the European Union (EU) member states. An econometric model is developed in which capacity additions are explained according to several variables (wind resource potentials, support levels, electricity generation costs, type of support scheme, administrative barriers, social support for wind electricity, the general investment climate in the country, electricity demand, the share of other low-carbon technologies, country area and whether there have been major or minor changes in the support scheme). The results show that capacity additions are significantly and negatively related to administrative barriers and changes in the support scheme and positively and significantly related to the general investment climate. The other variables are not statistically significant, although they generally have the expected sign. The results suggest that, more than the level of support granted to renewable energy technologies and the wind resource potentials of each country, capacity additions are encouraged by the removal of administrative barriers and by greater regulatory stability, leading to lower investment risks.

13/01706 Comparison of the financial attractiveness among prospective offshore wind parks in selected European countries

Prüssler, T. and Schaechtele, J. *Energy Policy*, 2012, 45, 86–101.

Offshore wind power is regarded as a crucial renewable energy technology to achieve the ambitious CO_2 reduction targets of the European Union. However, offshore wind power is not yet competitive with traditional electricity generation technologies, so its sustained development depends on national support policies. Employing a discounted cash flow model, this paper scrutinizes how national regulations and geographic conditions of designated national offshore wind development areas affect profitability. The focus of the analysis is on a set of hypothetical offshore wind park scenarios from five countries (Belgium, Denmark, Germany, France and the UK). The inclusion of geographic conditions is significant, since water depth and distance to shore influence costs and because available wind resources determine the amount of electricity produced. The paper's findings are threefold: first, profitability results indicate that currently relevant scenarios in the UK and Germany are most attractive, but that the upcoming UK Round III projects have low attractiveness. Belgium, France, and Denmark follow in the rankings successively. Second, there is high variation among scenarios with respect to capital costs – differences amount up to +61%. Finally, a future scenario assuming technology improvements and learning effects suggests that remuneration levels could be lowered by ~25% by 2020.

13/01707 Dynamic modeling and robust power control of DFIG driven by wind turbine at infinite grid

Kassem, A. M. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 375–382.

In this paper, a dynamic modelling and power control scheme for doubly-fed induction generator (DFIG) for variable speed wind power generation is proposed. A detail dynamic model of a DFIG-based, wind turbine and grid-connected system is presented in the d - q -synchronous reference frame. A robust controller based on sliding mode controller (SMC) is applied in order to control the power flowing between the stator of the DFIG and the power network. To improve the controller performance in steady state the integral sliding mode controller (ISMC) is used. Also, ISMC is used to achieve the controller robustness. Its respective performance is compared in terms of power reference tracking, sensitivity to perturbations in sub-synchronous and super-synchronous modes and robustness against machine parameters variations. Moreover, the proposed ISMC performance is compared with the conventional proportional–integral control.

13/01708 Energy storage system-based power control for grid-connected wind power farm

Ge, B. et al. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 115–122.

Wind power is characterized as intermittent with stochastic fluctuations, which can result in deviation of grid frequency and voltage when the wind power ratio is high enough. These effects have a definite impact on stability and power quality of grid operation. This paper proposes an energy storage system (ESS) based power control for a grid-connected wind power system to improve power quality and stability of the power system. Vanadium redox flow battery (VRB), as an environmentally-friendly battery provided with many advantages, is employed in the ESS. A dynamic mathematical model of VRB is built by using an equivalent circuit, and its charging and discharging characteristics are analysed. The VRB's stable voltage is available in a wide range (around 20–80% state of charge), which is suitable for utilization of a single-stage AC/DC converter in the VRB-based ESS. With a proposed energy storage control method, VRB-based ESS is added at the exit of the grid-connected wind farm to filter fluctuations of wind power, which ensures that smooth power will be injected into the grid and which improves power quality of the power system. Simulations and experiments are carried out to verify the proposed power control method for these grid-connected wind power systems. The grid-connected wind farm with VRB-based ESS, wind speed (characterized as gust and stochastic wind), and wind turbines are modelled in simulations. Simulation results show that the grid-injected active power from the wind farm is effectively smoothed, and reactive power support can be provided for the grid by the designed VRB-based ESS. Experimental verification is achieved with a low power bench, where a RT-LAB real-time simulation platform and a direct torque controlled induction motor simulate a real wind turbine and a wind speed model is built in the RT-LAB real-time simulation platform. The experimental results verify the proposed scheme through demonstrating a stable and smooth power flow injected into the grid though the wind power fluctuated.

13/01709 Evaluating energy storage technologies for wind power integration

Sundararagavan, S. and Baker, E. *Solar Energy*, 2012, 86, (9), 2707–2717.

In this paper, the authors perform a comparative analysis of various storage technologies that are useful for mitigating unpredictability caused by the integration of wind power into the electric grid. The authors identified three key applications of electric energy storage systems in relation to wind integration, namely, load shifting, which uses off-peak storage for on-peak dispatch at the system level; frequency support at the transmission and distribution level; and power quality, which aids in smoothing fluctuations at the distribution level. No single technology dominates all three applications, although compressed air energy storage (CAES) comes close. It has the lowest cost for both load shifting and frequency support, and the third lowest cost for power quality after flywheels, and superconducting magnetic energy storage (SMES). Flywheels and lead-acid are cost-effective on all applications, with flywheels having the second lowest cost for power quality and frequency support, and the fifth lowest for load-shifting. Lead-acid ranks third, third and sixth on load-shifting, frequency support and power quality, respectively. CAES has the lowest cost for the combined application, followed by pumped hydro storage, under the assumption that these technologies can be designed at a smaller scale in the future. However, these technologies may be of limited use, since they require particular geological formations to be available; pumped hydro storage in particular is unlikely to see many improvements in cost or efficiency through technological change, while the need for underground caverns and salt mines are significant hurdles for CAES. The authors find that significant improvements are needed for all of the other technologies, even to match the cost of lead-acid. They note that lead-acid is already considered much too expensive to be viable on a large scale. The energy costs of flywheels and Ni–Cd would need to be reduced by 22% and 55% in order to bring their costs in line with lead-acid. EC and Li-ion, some of the more talked about alternatives, would need to reduce energy costs by nearly 90%. A focused effort aimed at sodium–sulfur (NaS) that reduced the power cost by about 67% and energy costs by about 43% would make it better than lead-acid; a reduction of energy cost by 70% and power cost by 90% would make it competitive with CAES. Similarly, for ZnBr, a reduction of energy cost by 63%, and power cost by 85% would make it superior to Pb-acid batteries and competitive to CAES. Assumptions about interest rates play an important role in differentiating between the technologies. What constitutes good technologies depends importantly on the perspective of the decision maker. On the other hand, the efficiency and the lifetime of the technologies were less important factors. An important direction for future work would be to perform similar analyses for storage technologies integrated with solar photovoltaics or biomass.

13/01710 Evaluating the quality of scenarios of short-term wind power generation

Pinson, P. and Girard, R. *Applied Energy*, 2012, 96, 12–20.

Scenarios of short-term wind power generation are becoming increasingly popular as input to multistage decision-making problems, e.g. multivariate stochastic optimization and stochastic programming. The quality of these scenarios is intuitively expected to substantially impact the benefits from their use in decision-making. So far however, their verification is almost always focused on their marginal distributions for each individual lead time only, thus overlooking their temporal interdependence structure. The shortcomings of such an approach are discussed. Multivariate verification tools, as well as diagnostic approaches based on event-based verification are then presented. Their application to the evaluation of various sets of scenarios of short-term wind power generation demonstrates them as valuable discrimination tools.

13/01711 Ex post analysis of economic impacts from wind power development in U.S. counties

Brown, J. P. et al. *Energy Economics*, 2012, 34, (6), 1743–1754.

Wind power development has surged in recent years in the USA. Policymakers and economic development practitioners to date have typically relied on project-level case studies or modelled input–output estimates to assess the economic development impacts from wind power, often focusing on potential local, state-wide, or national employment or earnings impacts. Building on this literature, the authors conduct an *ex post* econometric analysis of the county-level economic development impacts of wind power installations from 2000 through 2008 in a large, wind-rich region in the country. Taking into account factors influencing wind turbine location, an aggregate increase was found in county-level personal income and employment of approximately \$11,000 and 0.5 jobs per megawatt of wind power capacity installed over the sample period of 2000 to 2008. These estimates appear broadly consistent with modelled input–output results, and translate to a median increase in total county personal income and employment of 0.2% and 0.4% for counties with installed wind power over the same period.

13/01712 Experimental investigation on the performance of an autonomous wind energy conversion system

Abdelkafi, A. et al. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 581–590.

Distributed generation seems to be a very interesting solution to provide electricity especially for the remote areas far from the electrical grid. In this paper, an autonomous wind energy conversion system and the control strategies applied to feed an isolated site were presented. A test bench was achieved in order to emulate the behaviour of a variable speed wind turbine connected to isolated loads. This study shows that the use of resonant controllers ensures the stability of the three-phase source supplying the loads, which may be unbalanced and subjected to abrupt variations. A comparison between simulation and experimental results proves the effectiveness of the test bench and the control strategies implemented in real time.

13/01713 Extent and types of small-scale wind policies in the U.S. states: adoption and effectiveness

Wiener, J. G. and Koontz, T. M. *Energy Policy*, 2012, 46, 15–24.

Renewable energy sources, including wind, are increasingly promoted by US state governments. Using state-level data and survey responses from energy officials in 44 states, this study catalogues the extent and types of small wind policies adopted by states. It examines the factors correlated with policy adoption, and perceptions about which policy tools are most effective. Results indicate that 84% of the states participating in the survey have adopted at least one policy to promote small wind technologies, and most have adopted several policies. The most frequent policy is net metering, and this policy tool was also perceived to be one of the most effective at encouraging businesses and consumers to install small wind technologies. However, several other policy tools perceived to be most effective at promoting small wind installations have been adopted by relatively few states. This identified gap suggests opportunities for improving policy effectiveness. In explaining factors associated with adoption of policy tools, the authors find support for variables comprising both the policy diffusion and internal determinants models of policy adoption, including state commitment to environmental protection and policy innovations, citizen ideology, per capita wealth, energy policy network communications, and desire to be viewed as an environmental leader.

13/01714 Formation of competences to realize the potential of offshore wind power in the European Union

Jacobsson, S. and Karltorp, K. *Energy Policy*, 2012, 44, 374–384.

The electricity sector has to undergo a large-scale transformation process to reduce the threat of climate change. Wind power has a strategic role to play in this process. This paper makes a preliminary assessment of the types and numbers of engineers required to sustain a

large-scale expansion of offshore wind energy in the European Union and draws lessons for universities. A variety of competences are required, including (a) deep competences in many fields (electrical and mechanical engineering, but also engineering physics and civil engineering); (b) integrative competences within engineering (e.g. mechanical and electrical engineering) and between engineering and non-engineering fields (e.g. meteorology and logistics). A large number of engineers are required. A rough estimate indicates a need for more than 10,000 new engineers until 2020. The nature and volume of the competences required raise serious questions for the scale and organization of training programmes at universities.

13/01715 Impact of wind turbine blade rotation on the lightning strike incidence – a theoretical and experimental study using a reduced-size model

Radičević, B. M. *et al. Energy*, 2012, 45, (1), 644–654.

The influence of wind turbine blade rotation on the lightning behaviour is not sufficiently studied. The original theoretical analysis and experimental investigation, whose most important segments are described in this paper, should enable a better understanding of this phenomenon. The tests were conducted in the high-voltage laboratory, applying the up-and-down method for determination of the 50% flashover standard switching voltage. The impulse voltage waves were applied between the specially designed arching electrode and/or the several rod electrodes at discrete positions along the insulating arching cylinder and the blades of a reduced-size wind turbine model, driven by a frequency controlled motor. A lightning protection system in the form of receptors on the tips of the blades was examined. According to the theory of similarity the paper discusses the characteristics of direct atmospheric discharges for the several typical rotational speeds of the wind turbine. It was concluded that the number of direct lightning strikes in the zone of the air termination system on the blades is decreasing due to the rotation of the blades.

13/01716 Improving power quality of wind energy conversion system with unconventional power electronic interface

Gidwani, L. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 445–453.

The increasing interest to utilize wind energy as a power source prompted more researches to be dedicated to the unconventional integration of this power source into the current grid. In this paper, one avenue to achieve this efficient utilization, through the use of integrated wind energy conversion system using doubly fed induction generator (DFIG) is presented. Wind grid integration brings the problems of voltage fluctuation and harmonic distortion. This paper presents an unconventional power electronic interface (UPEI) to reduce the total harmonic distortion (THD) and enhance power quality during disturbances. The models used in the paper includes a pitch-angled controlled wind turbine model, a DFIG model, power system model and an UPEI having controlled converters. A phase to phase fault is simulated on 132 kV bus and the measured results obtained from grid connection of the wind generation system are presented. The results have demonstrated the ability of UPEI to regulate pitch angle, VAR and to reduce THD. The proposed system increases the effectiveness of the utilization of wind energy.

13/01717 Intelligent speed sensorless maximum power point tracking control for wind generation system

Chen, C. H. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 399–407.

A sensorless vector-control strategy for an induction generator (IG) operating in a grid-connected variable speed wind energy conversion system is presented. The sensorless control is based on a model reference adaptive system (MRAS) observer for estimating the rotational speed. An on-line training recurrent neural network (RNN) controller using back-propagation learning algorithm with particle swarm optimization (PSO) is designed to allow the rotational speed adjustment for power regulation. The node connecting weights of the RNN are trained online by back-propagation (BP) methodology. The PSO is adopted to adjust the learning rates in the BP process to improve the learning capability. The proposed output maximization control is achieved without mechanical sensors such as wind speed or position sensor, and the new control system will deliver maximum electric power with light weight, high efficiency, and high reliability. The concept has been developed and analysed using a turbine directly driven IG.

13/01718 Introduction of a wind powered pumped storage system in the isolated insular power system of Karpathos–Kasos

Al. Katsaprakakis, D. *et al. Applied Energy*, 2012, 97, 38–48.

This paper presents a power production system for the isolated insular power system of the islands Karpathos and Kasos. Karpathos and Kasos are two small islands, located in the south-east Aegean Sea

(Dodecanese complex) that are not connected to the main power distribution network. Energy production is based exclusively on an autonomous thermal power plant and a small wind park, installed on the island of Karpathos. The maximum annual power demand has been estimated to exceed 12 MW by 2014. The mean specific annual energy production cost from the existing system has been calculated at €0.249/kWh in 2008. The proposed system aims at the maximization of wind energy penetration and the minimization of imported fossil fuel use for the production of electricity. The proposed system consists of a wind park and a pumped storage system (PSS). The introduced power system aims to guarantee power production for certain hours per day. A thorough sitting of the system is accomplished. Three different sites for the PSS installation are examined before the optimum is selected. The available wind potential of the islands was evaluated using a wind mast installed within the frame of the examined project's feasibility study. The annual mean wind velocity at the wind park's installation site was measured to be higher than 11.5 m/s. The introduced system's set-up, and operation and maintenance cost parameters have been estimated. The dimensioning of the system aims mainly at optimizing the project's economic indexes, following the existing legislative framework. The annual guaranteed energy production has also been maximized. An economic sensitivity analysis is performed. It is estimated that the proposed project can exhibit attractive economic indexes, regardless of the availability of a subsidy, on the condition that the selling price of energy should be configured at €0.3552/kWh and the selling price of guaranteed power should be €127/kWyear. Under the above mentioned prerequisites, the project payback period is estimated at 5–6 years. The present paper proves the economic feasibility of small scale wind powered pumped storage systems, not taking into account the undoubted environmental benefits.

13/01719 Large scale technical and economical assessment of wind energy potential with a GIS tool: case study Iowa

Grassi, S. *et al. Energy Policy*, 2012, 45, 73–85.

The development of new wind energy projects requires a thorough analysis of land use issues and constraints. At ETH Zurich, Switzerland, an analytical approach has been developed using a geographic information system (GIS) to define the location of suitable sites for wind projects and to predict their economic exploitable energy production. The purpose is to estimate the average annual energy production (AEP), with a GIS customized tool, based on physical factors (environmental and anthropological constraints), the wind resource distribution and the technical specifications of the large-scale wind turbines currently present in the US market. Economics data and regulatory parameters are also included. The wind energy potential of the state of Iowa has been estimated: the resulting average AEP of Iowa is 914 TWh and the potential total installed capacity is 302 GW. A sensitivity analysis of the influence of the power purchase agreement (PPA) shows that a PPA of \$0.065/kWh would enable to exploit the 85% of the buildable land with an IRR greater than 15%. This approach is applicable to both larger and more limited regions in order to support energy planners and wind farm developers to set energy strategies and to scout new profitable lands.

13/01720 Modeling of wind energy in some areas of Palestine

Kitaneh, R. *et al. Energy Conversion and Management*, 2012, 62, 64–69.

The daily mean wind speed data for four locations in Palestine over a period of 5 years are collected, analysed, and fitted to the Weibull distribution function. Weibull parameters are derived from the cumulative function of the observed data records (1997–2001), and used to calculate the mean wind speed and variance of the theoretical distribution. A quadratic polynomial is employed to fit the relationship between the wind power and the mean wind speed. The monthly mean wind power density found to be higher during summer and lowers during winter in most locations. However, in Hebron district the winter months have higher values than those for summer. The highest mean power values were 32.98 W m^{-2} in January and 37.85 W m^{-2} in July for Hebron and Nablus, respectively. The lowest mean power was 1.66 W m^{-2} in January for Jericho. The adjusted R^2 of the polynomial fit was about 99% for all stations except for Hebron was about 70%.

13/01721 Multi-objective economic emission load dispatch solution using gravitational search algorithm and considering wind power penetration

Mondal, S. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 282–292.

In this paper an economic emission load dispatch (EELD) problem is solved to minimize the emission of nitrogen oxides (NO_x) and fuel cost, considering both thermal generators and wind turbines. The effects of wind power on overall NO_x emissions are also investigated. To find the optimum emission dispatch, optimum fuel cost, best compromising emission and fuel cost, a newly developed optimization technique, called the gravitational search algorithm (GSA) has been applied. GSA

is based on the Newton's law of gravity and mass interactions. In GSA, the searcher agents are collection of masses which interact with each other using laws of gravity and motion of Newton. An IEEE 30-bus system having six conventional thermal generators has been considered as a test system. Two extra wind turbines are also placed at two weak load bus of the system. Two weak load buses have been selected based on their L -index value. After placing the wind power sources, those buses have been considered as generator bus. Minimum fuel cost, minimum emission and best compromising solution obtained by GSA are compared with those of biogeography-based optimization. The results show that the GSA surpasses the other available techniques in terms of solution quality and computational efficiency.

13/01722 Optimization of specific rating for wind turbine arrays coupled to compressed air energy storage

Succar, S. *et al. Applied Energy*, 2012, 96, 222–234.

A methodology is presented for jointly optimizing the wind turbine specific rating and the storage configuration for a large-scale wind farm coupled to compressed air energy storage (CAES). By allowing the wind-storage system to be optimized in an integrated, variable rating framework the levelized cost of electricity (LCOE) can be reduced substantially. These changes also enhance the capacity factor of the wind farm, reduce the storage capacity requirements of the baseload plant and reduce the greenhouse gas emission rate of the combined system relative to a separately optimized wind farm coupled to CAES. The results of this analysis could have important implications for the competitiveness of large-scale remote wind and the applicability of energy storage as a baseload wind strategy in a carbon constrained world.

13/01723 Penetration impact of wind farms equipped with frequency variations ride through algorithm on power system frequency response

Attya, A. B. and Hartkopf, T. *International Journal of Electrical Power & Energy Systems*, 2012, 40, (1), 94–103.

This paper presents a detailed analysis for the effect of wind farm connection to a certain power system on the system frequency response. Most wind farm parameters were considered, namely, the actual wind speeds, wake effects inside the wind farm, the different arrangements of wind turbines inside the wind farm and pitch control mechanism. Moreover, the major data of a power system were included; different conventional generation technologies and their suitable speed governors. In addition, instant dynamic load variations were implemented. Five case studies were conducted through this system to test the system frequency attitude during normal operation and in case of sudden and large load changes. Three basic values were used to estimate the mentioned impact; the time needed to reach the safe margin after a certain droop, the root mean square value of frequency deviation after the fault initiation by a given fixed time span and the maximum frequency drop for each event. All the previously stated studies were performed using MATLAB and Simulink simulations depending on real wind speeds data. The results proved the efficiency of the proposed algorithm even at relatively high load changes events (7–9% of S_N). Moreover, the criterion used to replace the conventional generator caused a slight deviation in the performance of the system frequency. It should be mentioned that results will change if these events occurred at different time intervals due to the variations in wind speed. To overcome this problem; several experiments should be simulated so that intended events are executed at different conditions. The obtained results should go through an averaging Monte Carlo process to evaluate the probability of different possibilities. Several case studies and possibilities could be considered in this point of research in the future. The effect of wind speeds variation through the four seasons of the year will be compared and the impact of changing the incident angle of the incoming wind stream. The kinetic energy available in each wind turbine will be quantized so that system frequency response is not the only factor to judge the wind farm performance during frequency droops. The supporting active power injected by the wind farm should be related to the amount of power loss and not a fixed amount.

13/01724 Probabilistic load flow for voltage assessment in radial systems with wind power

Vicente, W. C. B. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 41, (1), 27–33.

Exploitation of renewable energy sources in power networks, especially wind energy, is considered an alternative for power generation as a non-polluting source with a low environmental impact and low operational cost. Hence, renewable energy has motivated the increment of penetration of distributed generation in distribution networks and the development of methodologies to evaluate their effects in the electrical system, which is characterized by uncertainties at all levels (generation, network and load). In this paper, a new analytical approach is explored to formulate and solve the probabilistic load flow (PLF), which shows the voltage profile of a network including

uncertainties of power injections and consumption. This approach is based on the linearization of load flow equations for radial distribution systems using the probabilistic arithmetical laws. The solution is compared to Monte-Carlo simulation, which is the most common simulation used to solve the PLF problem.

13/01725 Robust nonlinear control of wind energy conversion systems

Kamal, E. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 202–209.

This paper presents stability analysis for a class of uncertain non-linear systems and a method for designing robust fuzzy controllers to stabilize the uncertain non-linear systems. First, the Takagi-Sugeno (TS) fuzzy model is adopted for fuzzy modelling of the uncertain non-linear system. Next, new stability conditions for a generalized class of uncertain systems are derived from robust control techniques such linear matrix inequalities (LMIs). The derived stability conditions are used to analyse the stability of Takagi and Sugeno's fuzzy control systems with uncertainty which can be regarded as a generalized class of uncertain non-linear systems. The design method employs the so-called parallel design approach (PDA). TS fuzzy systems are classified into three families based on the input matrices and a robust fuzzy controller's synthesis procedure is given for each family. In each family, sufficient conditions are derived for robust stabilization in the sense of Taylor series stability, for the TS fuzzy system with parametric uncertainties. Important issues for the stability analysis and design are remarked. The effectiveness of the proposed controller design methodology is finally demonstrated through the two different models of wind energy systems to illustrate the effectiveness of the proposed method.

13/01726 Robust voltage control of a stand alone wind energy conversion system based on functional model predictive approach

Kassem, A. M. *International Journal of Electrical Power & Energy Systems*, 2012, 41, (1), 124–132.

This paper investigates the application of the model predictive control (MPC) approach to control the voltage and frequency of a stand-alone wind generation system. This scheme consists of a wind turbine, which drives an induction generator feeding an isolated load. A static reactive power compensator (SVAR) is connected at the induction generator terminals to regulate the load voltage. The rotor speed, and thereby the load frequency are controlled via adjusting the mechanical power input using the blade pitch-angle control. The MPC is used to calculate the optimal control actions including system constraints. To alleviate computational effort and to reduce numerical problems, particularly in large prediction horizon, an exponentially weighted functional model predictive control (FMPC) is employed. Digital simulations have been carried out in order to validate the effectiveness of the proposed scheme. The proposed controller has been tested through step changes in the wind speed and the load impedance. Simulation results show that adequate performance of the proposed wind energy scheme has been achieved. Moreover, this scheme is robust against the parameters variation and eliminates the influence of modelling and measurement errors.

13/01727 Rotor power control in doubly fed induction generator wind turbine under grid faults

Hachicha, F. and Krichen, L. *Energy*, 2012, 44, (1), 853–861.

This paper is interested in the control of a wind energy conversion system (WECS) based on the doubly fed induction generator (DFIG) under grid fault conditions. A single line to ground fault and a double line to ground fault are tested during the hyper-synchronous operation of the DFIG wind turbine. In order to manage the rotor power flow in case of fault, a control technique of the grid side converter (GSC) is proposed. It is found that, three controllers are necessary to control the line currents of the rotor side connection because of the power unbalance during the faults. Simulation results are presented to show some operating conditions of the DFIG wind turbine and to prove the effectiveness of the proposed control technique.

13/01728 Sizing of a wind charger at minimum cost for remote housing electrification: a case study for nine coastal sites in Malaysia

Khatib, T. *et al. Energy and Buildings*, 2012, 51, 185–190.

In this research, the feasibility of small wind chargers for remote housing electrification in Malaysia is examined. Hourly wind speed data for nine coastal sites in Malaysia namely Bintulu, Kota Kinabalu, Kuala Terengganu, Kuching, Kudat, Mersing, Sandakan, Tawau and Pulau Langkawi are used. The proposed wind charger is supposed to supply night lighting load (84 Wh/day) with 1% loss of load probability. Mathematical models for the wind turbine and the storage battery in the proposed system are developed using MATLAB. However, the

results show that the cost of the energy produced by the proposed wind charger is in the range of US\$0.38–0.83/kWh. Such system is helpful for remote housing electrification in Malaysia.

13/01729 Thermodynamic assessment of a wind turbine based combined cycle

Rabbani, M. *et al. Energy*, 2012, 44, (1), 321–328.

Combined cycles use the exhaust gases released from a gas turbine (GT). Approximately 30–40% of the turbine shaft work is typically used to drive the compressor. The present study analyses a system that couples a wind turbine (WT) with a combined cycle. It demonstrates how a WT can be used to supply power to the Compressor in the GT cycle and pump fluid through a reheat Rankine cycle, in order to increase the overall power output. Three different configurations are discussed, namely high penetration, low penetration and wind power addition. In the case of a low electricity demand and high penetration configuration, extra wind power is used to compress air which can then be used in the low penetration configuration. During a high load demand, all the wind power is used to drive the pump and compressor and if required additional compressed air is supplied by a storage unit. The analysis shows that increasing the combustion temperature reduces the critical velocity and mass flow rate. Increases in wind speed reduce both energy and exergy efficiency of the overall system.

Others, including economics

13/01730 Analysis of U.S. residential wood energy consumption: 1967–2009

Song, N. *et al. Energy Economics*, 2012, 34, (6), 2116–2124.

The residential sector consumes about 23% of the energy derived from wood (wood energy) in the USA. An estimated error correction model with data from 1967 to 2009 suggests that residential wood energy consumption has declined by an average 3% per year in response to technological progress, urbanization, accessibility of non-wood energy, and other factors associated with a time trend such as increasing income per capita and number of houses. But the rising price of non-wood energy has had a positive effect on the consumption and offset the downward trend effect in the last decade. Residential wood energy consumption has also been sensitive to changes in wage rate in both the long and the short run, but the total estimated wage rate effect since 1967 is negligible. Wood energy is expected to continue to account for a small share of residential energy consumption unless public policies improve wood energy cost competitiveness relative to non-wood energy.

13/01731 Bioenergy production and use: comparative analysis of the economic and environmental effects

Hennig, C. and Gawor, M. *Energy Conversion and Management*, 2012, 63, 130–137.

This study analyses the use of liquid, solid and gaseous biomass for power generation in Germany with respect to the Renewable Energy Sources Act (EEG), a significant policy instrument for promoting electricity generation based on renewable energy sources. The aim is the identification of bioenergy conversion pathways that have a low environmental impact and are cost-effective. To achieve this objective several research steps were undertaken, including a life-cycle analysis (LCA), economic analysis and the determination of the CO₂ abatement costs. Besides, the authors show and discuss how a simplification of the environmental assessment by considering only the impact category greenhouse gases or the application of different calculation methodologies (i.e. allocation rules between electricity and heat produced) can affect the results. Overall the results show that the use of solid (wood) and gaseous biomass pathways causes both the lowest environmental impacts and electricity production costs when used for electricity generation. The choice of the modelling and calculation methodology may significantly influence the outcome (i.e. application of an exergetic allocation increases the environmental burden related to electricity generation). The lowest CO₂-abatement costs were determined for the biodegradable waste pathway.

13/01732 Correlations between biofuels and related commodities before and during the food crisis: a taxonomy perspective

Kristoufek, L. *et al. Energy Economics*, 2012, 34, (5), 1380–1391.

This paper analyses the relationships between the prices of biodiesel, ethanol and related fuels and agricultural commodities with a use of minimal spanning trees and hierarchical trees. To distinguish between short-term and medium-term effects, these trees were constructed for different frequencies (weekly and monthly). It was found that in short-term, both ethanol and biodiesel are very weakly connected with the other commodities. In the medium-term, the biofuels network becomes

more structured. The system splits into two well-separated branches – a fuels part and a food part. Biodiesel tends to the fuels branch and ethanol to the food branch. When the periods before and after the food crisis of 2007/2008 are compared, the connections are much stronger for the post-crisis period. This is the first application of this methodology on the biofuel systems.

13/01733 Electric cars and wind energy: two problems, one solution? A study to combine wind energy and electric cars in 2020 in The Netherlands

Bellekom, S. *et al. Energy*, 2012, 45, (1), 859–866.

To limit or, even better, reduce the emission of CO₂ and the corresponding global warming effects, measures should be taken in the two most polluting economic sectors: the energy and transport sectors. The Netherlands has set goals to reduce CO₂ emissions, in line with global and European initiatives. To reach this target, the electricity production sector should also use more renewables and the transport sector should take measures. In the electricity sector, the Netherlands wants to realize 10 GW of installed wind power in 2020; one of the initiatives for the transport sector is to have one million EVs (electric vehicles) in the same year. When EVs are powered with electricity from renewable sources, both sectors benefit; as such, it can 'kill two birds with one stone'. To study this, the authors researched the possible effects on the electricity system when introducing a large number of EVs and an increasing amount of wind power. The research presented models this for the 2020 Dutch situation. The study shows that the 2020 electricity system can cope with one million EVs and 10 GW of wind power, provided that EVs are charged using a load management regime that levels the nightly electricity demand.

13/01734 Evaluating risk-constrained bidding strategies in adjustment spot markets for wind power producers

Moreno, M. Á. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 703–711.

Participation of wind energy in the day-ahead electricity market implies large deviations from the initial schedule, which leads to costs for the wind farm owner. By means of short-term wind power prediction programs, the contracted energy can be updated in adjustment spot markets, reducing the power deviations and increasing the total revenue for wind power producers. Taking into account the different uncertainties involved in the problem, an optimal bidding strategy can be used to maximize the wind power producer revenues. As the strategy could be very risky due to all these uncertainties, a CVaR constraint for the bid that maximizes the expected revenue is proposed as a way of reducing the risk. A test-case using the Spanish market rules during a 10-month period has been used to check the potential benefits of the aforementioned strategies.

13/01735 Experimental wave termination in a 2D wave tunnel using a cycloidal wave energy converter

Siegel, S. G. *et al. Applied Ocean Research*, 2012, 38, 92–99.

A lift based cycloidal wave energy converter (CycWEC) is investigated in a 1:300 scale two-dimensional wave flume experiment. This type of wave energy converter consists of a shaft with one or more hydrofoils attached eccentrically at a radius. The main shaft is aligned parallel to the wave crests and submerged at a fixed depth. The operation of the CycWEC both as a wave generator as well as a wave-to-shaft energy converter interacting with straight crested waves is demonstrated. The geometry of the converter is shown to be suitable for wave termination of straight crested harmonic and irregular waves. The impact of design parameters such as device size, submergence depth, and number of hydrofoils on the performance of the converter is shown. For optimal parameter choices, experimental results demonstrate energy extraction efficiencies of more than 95% of the incoming wave energy. This is achieved using feedback control to synchronize the rotation of the CycWEC to the incoming wave, and adjusting the blade pitch angle in proportion to the wave height. Due to the ability of the CycWEC to generate a single sided wave with few harmonic waves, little energy is lost to waves radiating in the up-wave and down-wave directions.

13/01736 How market efficiency and the theory of storage link corn and ethanol markets

Mallory, M. L. *et al. Energy Economics*, 2012, 34, (6), 2157–2166.

This article uses the theories of market efficiency and supply of storage to develop a conceptual link between the corn and ethanol markets and explores statistical evidence for the link. The authors propose that a long-run no-profit condition is established in distant futures markets for ethanol, corn and natural gas and then use the theory of storage to define an inter-temporal equilibrium among these prices. The relationship shows that under certain conditions, future price expectations will influence nearby futures prices and that a short-term relationship between input and output prices will exist. The authors demonstrate validity of the theory using a structural price model and then by means of time-series techniques.

13/01737 Influence of household biogas digester use on household energy consumption in a semi-arid rural region of northwest ChinaDing, W. *et al. Applied Energy*, 2012, 97, 16–23.

A comprehensive investigation was conducted to evaluate the efficiency of newly installed biogas digesters in saving biomass resources and addressing energy squandering. Compared with traditional coal-based or firewood dominated energy consumption, the biogas digesters economize on energy resources due to higher heat efficiency. Furthermore, since crop residues of straw and other domestic animal and human excreta are effectively recycled and reused as anaerobic fermentation materials of biogas digesters, greenhouse gas emissions are significantly reduced by converting the previous extensive combustion of such into a sustainable and highly efficient practice in the rural region. The results in this study show that total energy consumption is 412 kgce (kgce: 1 kg standard coal, 1 kgce = 29.31 MJ) in Xiyang Township in 2009. The construction of biogas digesters significantly contributes to the transformation of rural household energy consumption structure, though biogas as a renewable energy only accounts for 6.31% of the total household energy consumption. Per capita rural household energy consumption is 393.07 kgce in household with biogas digesters and 437.60 kgce in household without biogas digesters. In addition, application of biogas dregs, slurry, and marsh liquid to the agricultural crops have greatly reduced the expenditure of buying chemical fertilizers. The average commercial fertilizer per *mu* (0.067 ha) in rural households using biogas digesters is 12.43 kg and the cost per *mu* is 29.53 yuan (1 yuan = US\$0.1523), while rural households without biogas digesters use 25.22 kg of commercial fertilizers and cost 59.71 yuan per *mu*. The utilization of biogas in rural semi-arid regions of China is a potentially clean development mechanism and has profound implications for applied energy.

13/01738 Integrated assessment of carbon capture and storage (CCS) in the German power sector and comparison with the deployment of renewable energiesViebahn, P. *et al. Applied Energy*, 2012, 97, 238–248.

If the current energy policy priorities are retained, there may be no need to focus additionally on carbon capture and storage (CCS) in the power plant sector of Germany. This applies even in the case of ambitious climate protection targets, according to the results of the presented integrated assessment study. These cover a variety of aspects. First, the technology is not expected to become available on a large scale in Germany before 2025. Second, if renewable energies and combined heat and power are expanded further and energy productivity is enhanced, there is likely to be only a limited demand for CCS power plants, as a scenario analysis of CCS deployment in Germany shows. Third, cost analysis using the learning curve approach shows that the electricity generation costs of renewable electricity approach those of CCS power plants. This leads to the consequence that, from 2020, several renewable technologies may well be in a position to offer electricity at a cheaper rate than CCS power plants. In addition, a review of new life cycle assessments for CO₂ separation in the power plant sector indicates that the greenhouse gas emissions from 1 kWh of electricity generated by first-generation CCS power plants could only be reduced by 68% to 87% (95% in individual cases). Finally, a cautious, conservative estimate of the effective German CO₂ storage capacity of approximately 5 billion tonnes of CO₂ is calculated, including a fluctuation range yielding values between 4 and 15 billion tonnes of CO₂. Therefore, the total CO₂ emissions caused by large point sources in Germany could be stored for 12 years (basic value) or for 8 or 33 years (sensitivity values).

13/01739 Modelling the economic impacts of 500 MW of wave power in IrelandDeane, J. P. *et al. Energy Policy*, 2012, 45, 614–627.

This paper investigates the impacts of including 500 MW of wave power into Ireland's electricity generation portfolio in the year 2020. One year of detailed market simulations are undertaken to determine the impact on wholesale electricity prices, system operation costs and CO₂ emissions with and without this installed wave power under a number carbon prices assumptions. In both scenarios (with and without wave energy), Ireland's installed renewable capacity is fixed such that 40% of Ireland's electricity in 2020 is from renewable source. The likely revenue a wave energy device would earn in the market is also investigated and compared with what is required to achieve 500 MW installed capacity. It is shown that in general the inclusion of wave energy has a negligible effect on wholesale electricity prices, reduces total system cost in Ireland and can increase CO₂ emissions on the island of Ireland under certain carbon price assumptions. It is also shown the current REFIT for wave energy is adequate.

13/01740 Multi-point aerodynamic optimization of the rotor blade sections of an axial-flow impulse air turbine for wave energy conversionGomes, R. P. F. *et al. Energy*, 2012, 45, (1), 570–580.

The oscillating water column (OWC) equipped with an air turbine is one of the most actively studied devices for wave energy conversion. It consists of a partially submerged hollow structure whose upper part forms an air chamber and whose immersed part is open to the action of the sea waves. The incident waves excite the internal free surface of the entrained water mass whose oscillation produces a reciprocating air flow that drives a turbine installed in a duct between the chamber and the atmosphere. This paper describes a new two-step method for the optimization of two-dimensional blade sections of an axial-flow impulse air turbine for OWC wave energy converters. Firstly, an inverse design method imposes an almost constant pressure-load along the axial chord by changing the camber line slope. Secondly, a thickness distribution optimization flattens the pressure distribution and decreases the suction peaks at the leading and trailing edges. An optimized geometry of an axial-flow self-rectifying impulse turbine rotor is presented to show the capabilities of the proposed methodology. The three-dimensional blade geometry is generated by stacking optimized sections along the spanwise direction. The rotor efficiency is computed through a three-dimensional computational fluid dynamics simulation for several flow rate conditions.

13/01741 Non-dimensional scaling of tidal stream turbinesMason-Jones, A. *et al. Energy*, 2012, 44, (1), 820–829.

The impact of local depth-wise velocity profiles on tidal turbine performance is important. Although the use of standard power laws for predicting velocity profiles is common, these laws may underestimate the magnitude of the depth-wise velocity shear and power attenuation. Predicting the performance of a tidal turbine in a high velocity shear is crucial in terms of power extraction. This paper discusses the dimensional scaling of a turbine using CFD and experimental data. Key performance characteristics (power, torque and thrust coefficients) were studied with increasing diameters and velocities, by generating a series of non-dimensional curves. This provides a first order approximation for matching turbine performance characteristics to site conditions. The paper also shows that the use of a volume-averaged velocity derived from the upstream velocity profile can be used to determine these key performance characteristics. These are within 2% of those determined assuming a uniform flow. The paper also shows that even changes in the blade pitch angle results in new turbine characteristics under uniform velocity conditions and it is expected that these can be used for profiled flow.

13/01742 Non-parametric and parametric modeling of biodiesel, sunflower oil, and crude oil price relationshipsHassounieh, I. *et al. Energy Economics*, 2012, 34, (5), 1507–1513.

Multivariate local linear regression and parametric error correction models are applied to assess price linkages and price transmission patterns between food and energy prices in Spain. Weekly biodiesel, sunflower and crude oil prices observed from November 2006 to October 2010 are used in the empirical analysis. Results suggest the existence of a long-run, equilibrium relationship between the three prices studied. Biodiesel is the only variable that adjusts to deviations from this long-run relationship. Local linear regression techniques show that the speed of adjustment of biodiesel prices is faster when biodiesel is relatively cheap than when it is expensive. Energy prices are also found to influence sunflower oil prices through short-run price dynamics.

13/01743 Parametric models for the performance of wave energy convertersPascal, R. *et al. Applied Ocean Research*, 2012, 38, 112–124.

Wave energy is an emerging and promising renewable energy technology. As the first pre-commercial and commercial prototypes are being tested at sea, there is a need for developers, governments and investors to be able to reliably estimate the energy production of devices as a function of the sea states they are to be deployed in. This estimation has traditionally relied on only two sea state parameters, the significant wave height and the energy period, but these do not account for frequency or directional spreading. The present paper investigates the suitability of further parameters to refine performance predictions. This is achieved through extensive wave tank testing of three types of wave energy converters (WECs) with different directionality properties. Statistical analyses of the measurements show the significant impact of frequency and directional spreading on the performance of WECs. Parametric models of the devices' performance were devised for numerous sea state parameters. These results suggest that the traditional estimation method should be extended in order to include at least a parameter related to the spectral bandwidth.

13/01744 Performance analysis of double blade airfoil for hydrokinetic turbine applicationsYavuz, T. and Koç, E. *Energy Conversion and Management*, 2012, 63, 95–100.

Hydrokinetic energy holds significant promise as a new, carbon-free energy source. The hydrokinetic turbine harnesses the power from moving water without the construction of a dam. Operational effectiveness of the wind and hydrokinetic turbines depend on the performance of the airfoils chosen. Traditionally, standard airfoils, like NACA and GÖTTINGEN, are used for wind and hydrokinetic turbines generating energy have the maximum lift coefficient about 1.3 at the stall angle of attack, about 12° . At these values, the flow velocities to produce electric energy are 7 and 3 m/s for wind turbine and hydrokinetic turbine respectively. Using double blade airfoil, the fluid dynamics governing the flow field eliminates the separation bubble by the injection of the high momentum fluid through the gap of the double blade of airfoil by meaning of the flow control delays the stall up to an angle of attack of 20° , with a maximum lift coefficient of 2.06. Hence, using double blade airfoils in the wind and hydrokinetic turbines, minimum wind and hydrokinetic flow velocities to produce economical energies will be 3–4 m/s for wind turbines and 1–1.5 m/s or less for hydrokinetic turbines. Consequently, the wind power and hydrokinetic potentials of Turkey will be re-defined and increased accordingly.

13/01745 Performance evaluation of hydropower generation system using transfer function modelling

Nwobi-Okoye, C. C. and Igboanugo, A. C. *International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 245–254. Poor electricity generation in Nigeria is a very serious problem. The low power generation is caused in part by the ineffective maintenance and inefficient performance of Nigeria's power generation facilities. The aim of this study is to develop a new and better way of evaluating the performance of hydropower generation facilities in order to improve their performance using transfer function modelling. It involves taking input-output data from a hydropower generation process over a 10-year period and developing transfer function models of the process for the 10 years, which are used as performance indicators. Based on the performance indicators obtained from the models, the results show that the efficiency of the power generation facility was worst in the year 2006 and best in 2003. Generally the indicators (coefficient of performance) were undulating over the 10-year period. Finally based on the fact the power plant has underperformed over the years, a value of coefficient of performance which must be above the highest coefficient of performance of 7.523 obtained was suggested as a benchmark below which a hydropower plant is assumed to have underperformed. The result of this study is expected to open new ways to improving maintenance effectiveness and operations efficiency of power generation facilities. The study would be of immense help in improving power generation in Nigeria and elsewhere.

13/01746 Prospects for pumped-hydro storage in Germany

Steffen, B. *Energy Policy*, 2012, 45, 420–429. After a period of hibernation, the development of pumped-hydro storage plants in Germany regains momentum. Motivated by an ever-increasing share of intermittent renewable generation, a variety of energy players considers new projects, which could increase the available capacity by up to 60% until the end of the decade. This paper analyses the current development and evaluates the revenue potential as well as possible barriers. Overall, the prospects for new pumped-hydro storage plants have improved, even though profitability remains a major challenge.

13/01747 Providing adequate economic incentives for bioenergies with CO₂ capture and geological storage

Ricci, O. *Energy Policy*, 2012, 44, 362–373. Knowing that carbon capture and storage (CCS) could play an important role in reducing emissions, it is important to have a good understanding of this role and the importance of environmental policies to support carbon capture and geological storage from bioenergies (BECCS). To date CCS technologies are not deployed on a commercial level, and policy instruments should be used to provide incentives to firms to use these technologies to reduce pollution. The aim of this paper is to compare the cost-efficiency of several incentive-based instruments (a fossil fuel tax, an emissions tax, a cap and trade system, and a subsidy on captured emissions) needed to spur the adoption of CCS and BECCS, using a dynamic general equilibrium model. This type of model has become the standard for assessing economy-wide impacts of environmental and technological policies. The study shows that BECCS will be deployed only if a specific subsidy per unit of biomass emissions captured with a CCS technology is available. The authors also show that the two most cost-efficient instruments for achieving a given emissions reduction target are a specific subsidy that rewards captured emissions and a carbon tax whose revenues are recycled to subsidize BECCS.

13/01748 Reverse power management in a wind diesel system with a battery energy storage

Sebastián, R. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 160–167. The subject of this paper is to present the modelling of a wind diesel hybrid system (WDHS) comprising a diesel generator (DG), a wind turbine generator (WTG), the consumer load, a Ni–Cd battery based energy storage system (BESS) and a distributed control system (DCS). All the models of the previously mentioned components are presented and the performance of the WDHS is tested through simulation. Simulation results with graphs for frequency and voltage of the isolated power system, active powers generated/absorbed by the different elements and the battery voltage/current/state of charge are presented for negative load and wind speed steps. The negative load step reduces the load consumed power to a level less than the WTG produced power, so that to balance active powers a negative DG power is needed (DG reverse power). As the DG speed governor cannot control system frequency in a DG reserve power situation, it is shown how the DCS orders the BESS to load artificially the system until the DG power falls in a positive power interval. The negative wind step decreases the WTG produced power, returning the power system to a situation where the needed DG power returns to positive, so that the BESS is not needed to load the system.

13/01749 Risk-limiting dispatch for integrating renewable power

Rajagopal, R. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 615–628. Risk-limiting dispatch (RLD) is formulated as the optimal solution to a multi-stage, stochastic decision problem. At each stage, the system operator (SO) purchases forward energy and reserve capacity over a block or interval of time. The blocks get shorter as operations approach real time. Each decision is based on the most recent available information, including demand, renewable power, weather forecasts. The accumulated energy blocks must at each time t match the net demand $D(t) = L(t) - W(t)$. The load L and renewable power W are both random processes. The expected cost of a dispatch is the sum of the costs of the energy and reserve capacity and the penalty or risk from mismatch between net demand and energy supply. The paper derives computable 'closed-form' formulas for RLD. Numerical examples demonstrate that the minimum expected cost can be substantially reduced by recognizing that risk from current decisions can be mitigated by future decisions; by additional intra-day energy and reserve capacity markets; and by better forecasts. These reductions are quantified and can be used to explore changes in the SO's decision structure, forecasting technology, and renewable penetration.

13/01750 Short-term hydrothermal generation scheduling using differential real-coded quantum-inspired evolutionary algorithm

Wang, Y. *et al. Energy*, 2012, 44, (1), 657–671. Short-term hydrothermal generation scheduling aims at determining optimal hydro and thermal generations to achieve minimum fuel cost of thermal plants for a 1 day or a 1 week while meeting various hydraulic and electric system constraints. The problem is viewed as a complex and non-linear hard problem considering valve-points effects and transmission losses with a set of operation operational and physical constraints. This paper presents a novel effective differential real-coded quantum-inspired evolutionary algorithm (DRQEA) for solving this complicated problem. Some improvements like real-coded rule, adaptive differential mutation and crossover mechanism are proposed in DRQEA to enhance the global search ability in continuous space. Meanwhile, various constraints are handled effectively by using heuristic strategies designed by their characteristics. The effectiveness of the proposed approach is demonstrated on two hydrothermal test systems, which consist of two sub-systems: hydro sub-system and thermal sub-system. The obtained results of the proposed approach are compared with other methods, and simulation and comparison results clearly show that DRQEA is able to provide better solution than other reported methods, both in the solution quality and the convergence speed. The proposed algorithm can also apply to other dynamic optimization problem with non-linear and non-convex characteristics in power system.

13/01751 Solving a woody biomass truck scheduling problem for a transport company in Western Oregon, USA

Han, S.-K. and Murphy, G. E. *Biomass and Bioenergy*, 2012, 44, 47–55. With rising fuel costs and enhanced environmental concerns, the use of renewable energy has been steadily considered and widely expounded as a solution to the challenges of global energy security and climate change. The use of woody biomass, in particular, has received considerable attention for energy production. However, high production and transportation costs can be a barrier to woody biomass utilization in some regions. Identifying or developing cost effective production and transportation systems has become an economically

critical issue to expand biomass utilization. The authors developed an optimization model to solve a truck scheduling problem for transporting four types of woody biomass in western Oregon. For an actual 50-load order size, the truck scheduling model produced significant improvements in solution values within 18 s. The average reductions in transportation cost and total travel time were 18% and 15%, respectively.

13/01752 The economics of short rotation coppice in Germany

Faasch, R. J. and Patenaude, G. *Biomass and Bioenergy*, 2012, 45, 27–40.

Short rotation coppice (SRC), which entails managing wood plantations as perennial energy crops on agricultural land, has the potential to contribute significant amounts of wooden biomass to Europe's energy mix. Yet, uncertainty prevails about the future of key economic variables determining the viability of SRC cultivations. Consequently, agriculturists face challenges when conducting *ex ante* economic analyses of SRC projects and measuring performance against the alternative, agricultural crops. This paper scrutinizes five key determinants of SRC economic viability: yield level, woodchip market price, subsidies, cost level and opportunity costs for conventional agricultural crops. By utilizing site-specific conditions and different future scenarios, the authors provide a comprehensive economic appraisal of SRC plantations for agriculturists. The authors focus their analysis on Germany. The results show that SRC plantations are less profitable under the medium scenario when compared with agricultural crops. Notwithstanding, favourable political and economic conditions such as subsidies, lower costs and higher woodchip prices can lead to SRC's superior profitability. If the German government is serious about improving investments conditions for commercial SRC plantations, the authors recommend introducing sufficient, efficient and consistent subsidies.

13/01753 The emergence of the biodiesel industry in Brazil: current figures and future prospects

Padula, A. D. *et al. Energy Policy*, 2012, 44, 395–405.

The aim of the present paper is to characterize and analyse the emergence of the biodiesel industry in Brazil, and provide an assessment of the extent to which the goals established by the National Biodiesel Production and Usage Program have been reached. In relation to the goal of including biodiesel within the Brazilian energy matrix, the program can be seen to be responding dynamically and ahead of schedule. In 2010, the B5 blend was already part of the diesel consumed in Brazil, with 81% of the biodiesel coming from soybean oil and 14% from beef tallow. By contrast, the plans to diversify the feedstocks used to produce biodiesel and improve production in the poorest regions of Brazil have failed to prosper. Regarding the goal of fostering social inclusion by encouraging the participation of family-based farming, this has been partially achieved. Finally, the goal of cost-efficiently producing biodiesel is far from being achieved. The economic feasibility of the production and use of biodiesel in Brazil can be questioned since it is still strongly supported by tax incentives and production and marketing subsidies.

13/01754 Use of a finite element model for the determination of damping and synchronizing torques of hydroelectric generators

Ranlöf, M. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 844–851.

Damping and synchronizing torque coefficients are calculated from time-stepped finite element simulations of a hydroelectric generator connected to an infinite busbar. The calculated torque coefficients are compared to those obtained from two-axis equivalent circuit simulations as well as classical analytical expressions. The influence of the damper winding type, and the size and nature of the system disturbance on the damping and synchronizing torques is explored. It is found that a finite element model of a hydroelectric generator typically exhibits both higher damping and synchronizing properties compared to a two-axis circuit equivalent of the same unit. In particular, the damping and synchronizing contributions from a continuous damper winding are substantially higher in the finite element model than in the equivalent circuit model. Moreover, explicit consideration of dynamic iron losses is found to not affect the damping and synchronizing torques predicted by the finite element model.

13/01755 Use of renewable energy sources in light of the 'New Energy Strategy for Europe 2011–2020'

Nagy, K. and Körmendi, K. *Applied Energy*, 2012, 96, 393–399.

The paper analyses the issues for consideration listed in the stock taking document 'New Energy Strategy for Europe 2011–2020' and explores the impact of their implementation on the use of renewable energy sources. The main objective of the paper is to introduce and provide a summary of the theoretical and methodological achievements required for an analysis of the implications of such an EU level

strategy. It also provides a summary of the results of the analysis of the impacts of the strategy on a specific field; namely, on the use of renewable energy sources. Contradictions inherent in the strategy are discussed as well, and a proposal is put forward to aid the resolution of these contradictions. The paper also points out that the further development of the theoretical and methodological achievements may result in the creation of a simulation model, the application of which could effectively aid the process of strategic planning and the testing of strategies prior to approval. Finally, the paper discusses how an European Union level and/or a global network of energy security centres could promote the development and implementation of an energy policy ensuring the appropriate utilization of renewable energy sources.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

13/01756 A rigorous approach for predicting the slope and curvature of the temperature–entropy saturation boundary of pure fluids

Garrido, J. M. *et al. Energy*, 2012, 45, (1), 888–899.

An accurate description of the geometry of the temperature–entropy (*T*–*S*) diagram is of fundamental importance for predicting the state of working fluids undergoing isentropic processes, as usually required for analysing the performance of refrigeration and power-generation systems. In this contribution, rigorous analytical expressions have been obtained for the first and second temperature derivatives of the entropy envelope along the vapour–liquid equilibrium (VLE) path of pure fluids. These relationships are valid from the triple point up to the critical state, and have been conveniently expressed in terms of Helmholtz's energy, thus yielding a generalized method able to describe the geometry of the *T*–*S* diagram from typical equation of state models. The customary classification of fluids in wet, isentropic or dry behaviour has been reduced to a simple criterion based on a new dimensionless function ψ and how its value compares with the value of the isobaric heat capacity of the ideal gas. Applications are presented for cubic models of the van der Waals type, specific multi-parameter equations, molecular-based models, and virial density expansions. From these results it is concluded that dry behaviour depends on the number of atoms that compose the molecule, and it will be generally observed in long-chained molecules.

13/01757 A semi-empirical method to calculate the permeability of homogeneously fluidized pyroclastic material

Burgisser, A. *Journal of Volcanology and Geothermal Research*, 2012, 243–244, 97–106.

This work postulates that highly polydisperse materials have an effective size distribution that controls permeability. Existence of such effective distribution implies that not all clasts participate to the permeable network resisting to gas flow and that clasts smaller than the minimal effective size are elutriated. When this clast is coupled to a generalized Blake–Kozeny equation, the resulting semi-empirical law links permeability to material properties only (bed void fraction, clast sizes and densities). After calibration of an experimental constant, it is able to replicate within $\pm 0.6 \log$ unit experimentally measured permeabilities of both loosely packed and expanded beds made of highly polydisperse (from 1 μm to 4 mm) pyroclastic deposits that were resampled so as to ensure homogeneous fluidization. The presence of an experimentally calibrated constant and the necessary absence of segregation during fluidization limit the extrapolation of the proposed law to any pyroclastic bed. Satisfactory fitting of the experimental values, however, confirms that the permeability of homogeneously fluidized beds is controlled by a balance between settling and elutriation. This balance suggests a first-order link between permeability and bed expansion, which has implications on the kinetics of dense pyroclastic flows.

13/01758 Acoustic waves generated by a TA (thermoacoustic) laser pair

Chun, W. *et al. Energy*, 2012, 45, (1), 541–545.

Sound waves and acoustic energy generated by two identical thermo-acoustic (TA) lasers were analysed and studied. Sound pressure level meters and microphones were employed to measure and study the sound waves at different distances from the openings of the TA laser pair for different laser position arrangements. The sound waves of the two TA lasers at or near the focusing point were found to be almost 180° out of phase when the distance between the openings of the two lasers was within about two tube diameters and the angle between the laser axes did not exceed 135°. As the distance increased, it became difficult to control the two TA lasers in synchronized operation. For separation distances greater than three times tube diameter, the sound wave amplitudes and the phase difference between the two laser outputs varied periodically with time. With the openings of the two TA lasers touching each other, the frequency of the sound waves increased when the angle between the laser axes was very close to 180°. In this case, the glass tube opening was no longer a pressure anti-node and the wavelength of the fundamental mode reduced to approximately twice the tube length.

13/01759 Advantages and disadvantages associated with introducing an extra rarefied gas layer into a rotating microsystem filled with a liquid lubricant: first and second law analyses

Shamshiri, M. *et al. Energy*, 2012, 45, (1), 716–728.

In this study, the effects of rarefaction, viscous dissipation, aspect ratio, and accommodation coefficients on transport characteristics associated with a two-phase flow within a rotating microsystem are investigated. It is assumed that centrifugal acceleration due to rotation separates the mixture into two immiscible gas and liquid layers. The incompressible Navier–Stokes–Fourier equations in the cylindrical reference frame are employed, while the effects of velocity slip and temperature jump phenomena for the gaseous phase are taken into account. Considering external heating influence and applying the classical thermal boundary conditions of uniform heat flux and constant wall temperature, three different thermal cases are constructed. Expressions for the velocity and temperature distributions of these thermal cases as well as the average entropy generation rate and the Bejan number pertained to the gas and liquid layers are presented. In addition, the criteria for evaluating the impact of the gas layer on shear and temperature reductions at the shaft and also irreversibility rise in the medium are discussed.

13/01760 Clear-sky irradiance predictions for solar resource mapping and large-scale applications: improved validation methodology and detailed performance analysis of 18 broadband radiative models

Gueymard, C. A. *Solar Energy*, 2012, 86, (8), 2145–2169.

The intrinsic performance of 18 broadband radiative models is assessed, using high-quality datasets from five sites in widely different climates. The selected models can predict direct, diffuse and global irradiances under clear skies from atmospheric data, and have all been (or still are) involved in large-scale applications, for instance to prepare solar resource maps and datasets, or to evaluate solar radiation in GIS software. The input data to the models include accurate aerosol and water vapour measurements by collocated sunphotometers, if needed. Cloud occurrences are meticulously scrutinized through the use of various tools to avoid cloud contamination of the test data. The intrinsic performance of the models is evaluated by comparison between their predictions and measurements at high frequency (1-minute time step at four sites, 3-minute at one site). The total expanded uncertainty of these measurements is estimated at 3% for direct irradiance, and 5% for diffuse and global irradiance. Various statistics are calculated to evaluate the systematic and random differences between the data series, as well as the agreement between the cumulative distribution functions. In the latter case, stringent statistics based on the Kolmogorov–Smirnov (KS) test are used. Large differences in performance are apparent between models. Those that require more atmospheric inputs perform usually better than simpler models. Whereas many models can predict the global horizontal irradiance within uncertainty limits similar to those of the radiation measurements, the prediction of direct irradiance is less accurate. Moreover, the prediction of diffuse horizontal irradiance is particularly deficient in most models. The cumulative distribution functions also denote areas of concern. A ranking of all models is proposed, based on four statistical indicators: mean bias difference, root mean square difference (RMSD), total uncertainty with 95% confidence limits (U_{95}), and the newly introduced combined performance index, which optimally combines two KS indices with RMSD. For direct irradiance, consistently high rankings are obtained with five models (REST2, Ineichen, Hoyt, Bird, and Iqbal-C, in decreasing order of performance) that require a relatively large number of atmospheric inputs. The inferior performance of models requiring little or no atmospheric inputs suggests that large-scale solar resource products derived from them may be inappropriate for serious solar applications. Additionally,

prediction uncertainties under ideal clear-sky conditions can propagate and affect all-sky predictions as well – resulting in potential biases in existing solar resource maps at the continent scale, for instance.

13/01761 Comparative monitoring and data regression of various sized commercial lightpipes

Su, Y. *et al. Energy and Buildings*, 2012, 50, 308–314.

This paper presents comparative monitoring of various sized commercial lightpipes at a purpose-built test shed with a pitched roof. The purpose of monitoring is to simultaneously compare the performance of lightpipes of different geometries and also to provide data for establishing a formula for performance prediction. The photometric integrating box, which Building Research Establishment Ltd has adopted as an approximation to the photometric integrating sphere, is employed to determine the lumen output of the lightpipes under real sky condition. This study presents monitoring of four sized lightpipes: straight Ø530 mm, elbowed Ø530 mm (with a tilted entrance), elbowed Ø450 mm and elbowed Ø230 mm. A mathematical model is proposed to correlate the measured lumen output, horizontal global illuminance, the diameter and length of the lightpipe, the specular reflectance, solar altitude and azimuth, and orientation of elbow if an elbowed lightpipe is tested. The coefficients in the formula are determined by regression of the monitoring data. The formula is then used to predict the lumen output of a lightpipe from the measured global illuminance for the given geometry and time. The agreement between the measured and predicted lumen output is generally satisfactory. The formula may be a useful design tool as it can predict the lumen output of a lightpipe from the global illuminance value such as those given in EnergyPlus weather data.

13/01762 Efficiencies of power flash cycles

Lai, N. A. and Fischer, J. *Energy*, 2012, 44, (1), 1017–1027.

Power flash cycles (PFC) are a generalization of trilateral cycles (TLC) in which the compressed liquid is heated up to its boiling point and then performs a flash expansion during which it delivers power. The end point of the expansion may be in the wet vapour region (TLC) or in the dry vapour region. Here model results are presented for PFC-systems including the heat transfer to and from the cycles with aromates, siloxanes and alkanes as working fluids. Optimization criterion is the exergy efficiency for power production at different pairs of heat carrier and cooling agent inlet temperatures ranging from (350°C, 62°C) to (150°C, 15°C). Comparisons with TLC for water, organic Rankine cycles (ORC) and water Clausius–Rankine cycles are made. General findings are that PFC has higher power production efficiencies than ORC but larger volume flows at the expander outlet. Moreover, TLC with water have in all cases the highest or nearly highest power production efficiencies. The disadvantages of water are the large outlet volume flows at low temperatures. For these cases alkanes like cyclopentane are to be preferred in PFC which can have significantly smaller outlet volume flows and rather high power production efficiencies.

13/01763 Entansy loss in thermodynamic processes and its application

Cheng, X. and Liang, X. *Energy*, 2012, 44, (1), 964–972.

The entransy theory has been developed for heat transfer optimization. This paper extends it to optimize thermodynamic processes. The entransy balance equation of thermodynamic processes is introduced, with which the concept of entransy loss is developed. For the Carnot cycle and the irreversible thermodynamic processes where the working fluid is heated by the streams with prescribed inlet temperatures and specific capacity flow rates, the maximum entransy loss leads to the maximum output work, which is the maximum principle of entransy loss in thermodynamic processes. However, the entropy generation cannot describe the change of the output work for the Carnot cycle. Therefore, the concept of entransy loss could describe the performance of thermodynamic processes. Then, the principle is used to optimize the thermodynamic processes of heat exchanger groups and the design of the irreversible Brayton cycle. For these problems, the operation parameters are optimized to get the maximum output work by calculating the maximum entransy loss when the entransy loss induced by dumping the used streams into the environment is considered. The analysis of the air conditioning system for room heating with heat–work conversion processes demonstrates the entransy loss has a direct relation with the input heat.

13/01764 Experimental study of the water in oil emulsions features by differential scanning calorimetry analysis

Mura, E. *et al. Applied Energy*, 2012, 97, 834–840.

The present work proposes a differential scanning calorimetric (DSC) analysis approach in order to characterize a W/O emulsion in function of the vaporization temperature of the inner water droplets. The correlation between the most probable boiling temperatures of the droplets and their radii involves the evaluation of the story of the released energy during the vaporization process. The experimental set-

up consists in a heat flow DSC system provided by a temperature programmable oven. A set of seven emulsions, containing the same amount of water, is classified in function of the dispersed water droplet diameters and tested several times. The resulting thermograms are statistically processed to obtain the most probable vaporization temperature for every emulsion in function of the dispersed water droplets size. The results show that the smaller the dispersed water droplet, the higher the vaporization temperature. Moreover, a notable degree of metastability, included in a range temperature from 5 to 10 °C, is pointed out and it is evident that it increases in reducing the dispersed water droplets size.

13/01765 Hydraulics of subaqueous ash flows as deduced from their deposits

Doronzo, D. M. and Dellino, P. *Journal of Volcanology and Geothermal Research*, 2012, 239–240, 12–18.

Subaqueous ash flows are gravity currents consisting of a mixture of sea water and ash particles. Also called volcanoclastic turbidity currents (VTCs), they can be generated because of remobilization of pyroclastic fall deposits, which are emplaced into the sea around a volcanic island, as well as far away, during an explosive eruption. The VTC upper part is the turbulent transport system for the flow, whereas the viscous basal one is the depositional system. Typical sequences of VTC deposits are characterized by cross-laminations, planar and convolute laminations, and massive beds, which reflect the stratified nature of the flow. Here, the analysis of some VTC hydraulic parameters is presented in order to depict flow behaviour and sedimentation during deposition. A reverse engineering approach is proposed, which consists of calculating hydraulic parameters by starting from deposit features. The calculated values show that a VTC is homogeneously turbulent for most of the thickness, but is viscous at its base. First, cross-laminations are directly acquired over the rough pre-existing seafloor, then planar or convolute laminations aggrade over the newly formed substrate. Finally, fine-grained suspended particles gently settle and cap the flow deposit.

13/01766 In-plane transport effects on hydrogen depletion and carbon corrosion induced by anode flooding in proton exchange membrane fuel cells

Yang, X. G. *et al. International Journal of Heat and Mass Transfer*, 2012, 55, (17–18), 4754–4765.

Anode flooding is frequently encountered in proton exchange membrane fuel cells, which can induce local hydrogen starvation and subsequently result in carbon corrosion in catalyst layers. This work develops a two-dimensional computational model and focuses attention on the mechanisms of hydrogen transport within the diffusion medium when part of the anode channel is clogged. In-plane convection is demonstrated to be the primary mechanism for hydrogen transport at the fringe of the flooded area. As the reactant flows deep inside, however, the dominating mechanism switches to diffusion due to nitrogen accumulation in the anode. Moreover, if hydrogen outside the flooded region is diluted with nitrogen, the length scale for hydrogen to deplete completely is reduced substantially, leading to an extension of the area suffering from hydrogen starvation and carbon corrosion. Meanwhile, the spatial distribution of carbon corrosion rate is emphasized in this work, and the effect of in-plane proton conduction is highlighted. This paper also sheds light on the maximum rate of carbon corrosion, which is demonstrated to be solely determined by oxygen crossover rate at high cell voltages, but is influenced by the kinetics of oxygen reduction reaction at low voltages.

13/01767 Interpreting tracer tests in the enhanced geothermal system (EGS) of Soultz-sous-Forêts using the equivalent stratified medium approach

Radilla, G. *et al. Geothermics*, 2012, 44, 43–51.

A new interpretation of tracer tests performed in 2005 in the French enhanced geothermal system located at Soultz-sous-Forêts is presented. A previous analysis of fluorescein tests revealed significant differences in terms of connectivity between the injection well (GPK3) and the two production wells (GPK2 and GPK4). The results suggested the existence of at least three fluid circulation loops. Two of them (loops 1 and 2) connecting GPK3 to GPK2, and the third one (loop 3) connecting GPK3 to GPK4. The present analysis is based on the equivalent stratified porous medium model, in which each circulation loop corresponds to a flow path through the rock formation and is regarded as a stratified porous medium having a log-normal permeability distribution. The heterogeneity of this equivalent porous medium is quantified by the stratification factor defined as the standard deviation to the mean permeability ratio. A very accurate fit of the concentration curves for both production wells was obtained. The stratification factors show that the three circulation loops have different levels of heterogeneity. The wellhead pressure recorded during the tests was used to calculate the mean permeability of the loops. Loop 1 appears to be very permeable and narrow while loops 2 and 3 are less permeable and wider. This tracer test model is compared to a new deterministic three-dimensional model of the fracture zones

observed in the Soultz granitic reservoir. A well-known major fault in the Soultz Graben intersecting GPK2 and GPK3 could explain the rapid tracer circulation in loop 1.

13/01768 Kinetic energy harvesting with bistable oscillators

Vocca, H. *et al. Applied Energy*, 2012, 97, 771–776.

The goal of powering small-scale electronic mobile devices with energy harvested from the ambient has been in recent years the subject of a great research effort. It has been observed that the harvesting of kinetic energy present in the form of random vibrations (from non-equilibrium thermal noise up to machine vibrations) is an interesting option due to the almost universal presence of this kind of motion. Present working solutions for vibration energy harvesting are based on oscillating mechanical elements that convert kinetic energy via capacitive, inductive or piezoelectric methods. These oscillators are usually designed to be resonantly tuned to the ambient dominant frequency. However, in most cases the ambient random vibrations have their energy distributed over a wide spectrum of frequencies, being rich especially at low frequency, and frequency tuning is not always possible due to geometrical/dynamical constraints. This paper discusses a different method based on the exploitation of the dynamical features of stochastic bistable oscillators employed to model non-linear piezoelectric harvesters. Such a method is shown to outperform standard linear oscillators and to overcome some of the most severe limitations of present approaches. The digitally simulated output response of a bistable piezoelectric energy harvester to real measured environmental vibrations is presented. The results of the simulations confirm the superior performances of this approach.

13/01769 Numerical solution of the multi-group integro-differential equation of the neutron diffusion kinetics in 2D-Cartesian geometry

Quintero-Leyva, B. *Annals of Nuclear Energy*, 2012, 48, 130–133.

The multi-group time-integro-differential equations of the neutron diffusion kinetics (IDE-NDK) was solved numerically using two-dimensional (2D) Cartesian geometry with the use of the basic-progressive polynomial approximation (BP_n). Two applications were computed: a ramp, and an instantaneous change of the thermal removal macroscopic cross sections of the driver material of the 2D-TWGL benchmark problems. The BP₂ algorithm showed good accuracy when compared with the results of other codes. BP_n did not show the undesirable oscillations that appeared in other codes.

13/01770 Pseudopillow fracture systems in lavas: insights into cooling mechanisms and environments from lava flow fractures

Forbes, A. E. S. *et al. Journal of Volcanology and Geothermal Research*, 2012, 245–246, 68–80.

Detailed field observations of structures within the flow front of a Holocene trachyandesite lava from Snæfellsnes, Iceland, are presented. The lava provides exceptional three-dimensional exposure of complex brittle and ductile deformation textures that record processes of lava fracture and quenching driven by external water. The flow front interior is characterized by structures consisting of a large (metre-scale) curvilinear master fracture with many smaller (centimetre-scale) subsidiary fractures perpendicular to the master fracture. Such structures have previously been recognized in a range of lava compositions from basalt to dacite and called pseudopillows or pseudopillow fractures. The authors propose the term 'pseudopillow fracture systems' to emphasize the consistent package of different fracture types occurring together. All documented occurrences of pseudopillow fracture systems are in lavas that have been inferred to interact with an aqueous coolant (i.e. liquid water, ice or snow). They use fracture surface textures and their orientation in relation to flow banding to identify three distinct types of master fracture and two types of subsidiary fractures. Master fracture surface textures used to identify fracture mechanisms include chisel marks (striae), cavitation dimples, river lines and rough/smooth fracture surface textures. These indicate both brittle and ductile fracture happening on different types of master fracture. Chisel marks on subsidiary fractures indicate comparative cooling rates, cooling directions and isotherm orientations at the time of fracture. The authors propose a model for pseudopillow fracture system formation taking into account all the various fracture types, textures and fracture propagation mechanisms and discuss their implications for interaction mechanisms between lava flows and external coolants.

13/01771 Results of experimental investigations on the heat conductivity of nanofluids based on diathermic oil for high temperature applications

Colangelo, G. *et al. Applied Energy*, 2012, 97, 828–833.

The work reported in this paper shows the experimental results from a study on diathermic oil based nanofluids. Diathermic oil finds application in renewable energy, cogeneration and cooling systems.

For example, it is used in solar thermodynamic or biomass plants, where high efficiency, compact volumes and high energy fluxes are required. Besides diathermic oil is very important in those applications where high temperatures are reached or where the use of water or vapour is not suitable. Therefore an improvement of diathermic oil thermo-physical properties, by using of nanoparticles, can increase the performance of the systems. In literature there are not many experimental data on diathermic oil based nanofluids because many experimental campaigns are focused on water nanofluids. Samples of nanofluids, with nanoparticles of CuO, Al₂O₃, ZnO and Cu, having different shapes and concentrations varying from 0% up to 3.0%, have been produced and their thermal conductivity has been measured by means of hot-wire technique, according to the standard ASTM D 2717-95. Measurements were carried out to investigate the effects of volume fraction, particle size of nanoparticles on the thermal conductivity of the nanofluid. The effect of temperature has been also investigated in the range 20–60 °C. A dependence was observed on the measured parameters and the results showed that the heat transfer performance of diathermic oil enhances more than water with the same nanoparticles.

13/01772 Subsurface temperature distribution in Germany

Agemar, T. *et al. Geothermics*, 2012, 44, 65–77.

Data from approximately 10,500 wells and more than 700 ground level data sets were used to develop a three-dimensional (3D) estimate of the subsurface temperature distribution in Germany. The temperature model was realized with universal kriging, and extends from ground level to 5000m below sea level. Conventional two-dimensional (2D) mapping algorithms are often used to estimate subsurface temperature at certain depths. The major limitation of any 2D mapping is the possibility of inconsistencies between different depths due to the loss of information from shallower levels. A different approach is used in this paper. The application of 3D-kriging in the context of subsurface temperature estimation is described in detail and variation of data density and quality are also discussed. Kriging employs customized prediction parameters for an unbiased estimate of the subsurface temperature distribution. The kriging variance predicts the uncertainty of the temperature estimate and provides a local probability interval of the temperature estimate. The developed temperature model is part of the geothermal information system for Germany.

13/01773 The production of a cellular graphene array by scanning probe lithography and its ability to store electrical charge

Yong, H. *et al. Carbon*, 2012, 50, (12), 4640–4647.

A graphene cellular array on an insulating SiO₂ layer was fabricated by scanning probe lithography. The graphene layer was oxidized by an electric field which was applied between the cantilever tip and Si substrate without any electrode directly connected to the graphene layer. When the bias voltage was applied on a cell of patterned graphene through the cantilever tip, charge was accumulated on the cell and preserved for a long time without decay. The accumulated charge and the surface potential were measured by an electrostatic force microscope. The charge retention was measured as a function of time, and the decay time constant was estimated to be ~70 min.

13/01774 Validation of the earth resistance formulae using computational and experimental methods for gas insulated sub-station (GIS)

Mohamad Nor, N. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 290–294.

This paper shows the mathematical formulas involved in obtaining the earth resistance value of a gas insulated sub-station (GIS) of 275/132 kV systems. It involves resistivity measurements and then interpretation of a two-layer soil model. Even though many studies have published work on earth resistance calculations, it is still important to obtain earth resistance by the measurements at field sites. In general, the earth resistance measurements are made in order to determine the actual resistance of the ground connections and as a check on calculations. In this study, the most common earth resistance measurement, which is a fall-of-potential method, was adopted. At field site, the experiments were conducted at least twice to double-check the measurements. From testing, it was found that the results for both experiments are found to give consistent results. The measured earth resistance value was found to be 0.5 Ω. This showed that only small discrepancies between the calculated and measured resistance values could occur. The discrepancies could be due to many factors such as listed in ANSI/IEEE 80:2000 standard, i.e. inadequacy of the analytical equations used in the resistance, inaccurate calculations, conditions of the soil, insufficient extent of the resistivity survey, inadequacy of the instrumentation used, and presence in the soil of adjacent metallic buried structures and ground wires which may divert a substantial amount of the test current.

13/01775 Variational principles in terms of entransy for heat transfer

Xu, M. *et al. Energy*, 2012, 44, (1), 973–977.

A variational principle for heat conduction is formulated which results in the steady state heat conduction equation established from the Fourier law. Furthermore based on the thermodynamics in terms of entransy a more general functional is defined for incompressible fluids. The authors show that extremizing this functional gives rise to the state described by the Navier–Stokes–Fourier equations with vanishing substantive derivatives of the temperature and velocity field. In this sense it may be concluded that this variational principle is consistent with the Navier–Stokes–Fourier equations. Therefore the variational principle developed in the present work demonstrates a great advantage over the minimum entropy production principle.

Fuel cell technology

13/01776 A combined capillary cooling system for fuel cells

Silva, A. P. *et al. Applied Thermal Engineering*, 2012, 41, 104–110.

Control of the operation temperature has an important influence over the performance of a proton exchange membrane fuel cell (PEMFC). In this study a two-phase heat transfer system is proposed as an alternative for the cooling and thermal control of a PEMFC. The proposed system consists of a capillary pumped loop (CPL) connected to a set of constant conductance heat pipes. Ceramic and stainless steel mesh wicks were used as the capillary structures of the CPL and heat pipes, respectively. Experimental results are reported herein for the separate components, i.e. three 1/8-inch diameter stainless steel heat pipes, one CPL and for the assembled cooling system. Different tests were performed for power inputs up to 50 W. Acetone was used as the working fluid for the CPL and deionized water for the heat pipes. All tests were considered successful, with the proposed system providing the required heat dissipation and maintaining the required temperature operation range for PEM fuel cells.

13/01777 A PEM fuel cell with metal foam as flow distributor

Tseng, C.-J. *et al. Energy Conversion and Management*, 2012, 62, 14–21.

This paper reports the experimental results of a proton exchange membrane (PEM) fuel cell with metal foam as flow distributor. These experimental results show the characteristics of the PEM fuel cell with the metal foam as flow distributor and extend the understanding of the relation between cell performance and mass transport properties into a region of parameters that the conventional PEM unit cell cannot provide. The comparison in polarization curve is made between the PEM unit cell with different metal-foam properties and the PEM unit cell with graphite flow channel plate as flow distributor. The experimental results show that the PEM fuel cell with metal foam as flow distributor possesses some unique characteristics compared with the conventional PEM unit cell with flow channel plate as flow distributor. The unique characteristics are listed in this paper with the preliminary analysis. Due to the high porosity of metal-foam (as high as 95%) plus convective flow through the metal-foam, mass transport limitation phenomenon is not as pronounced as in the case of conventional PEM unit cell with flow channel plate as flow distributor. Another interesting phenomenon is that electrical conductivity of metal-foam plays a significant role in performance, which is seldom the case in the conventional PEM unit cell with flow channel plate as flow distributor. Although there are several technical challenges to be overcome for the current form of metal-foam to replace flow channel plates, the unique mass-transport properties of metal foam plus its low weight are very attractive.

13/01778 A three-dimensional modeling of transport phenomena of proton exchange membrane fuel cells with various flow fields

Chiu, H.-C. *et al. Applied Energy*, 2012, 96, 359–370.

In this work, a two-phase three-dimensional numerical transport model based on the two-fluid method for the proton exchange membrane fuel cells (PEMFCs) with parallel flow field, interdigitated flow field, and serpentine flow field has been presented to study the cell performance and transport phenomena in the PEMFCs. The effects of width, height and aspect ratio of the flow channel on the cell performance and water removal with different flow fields are under investigation. Results show the liquid water removal increases as the channel height decreases, however, the cell performance decreases as well. It is also found that the cell performance decreases as the channel width increases in parallel flow field due to lower gas velocity with less water removal. The effect of a channel aspect ratio approximately equal to 1 is

particularly studied in this paper. It reveals that the cell performance is better as the channel cross-section area is smaller because of higher gas velocities.

13/01779 Effects of anisotropic permeability and electrical conductivity of gas diffusion layers on the performance of proton exchange membrane fuel cells

Ismail, M. S. *et al. Applied Energy*, 2012, 95, 50–63.

A three-dimensional model for an in-house proton exchange membrane (PEM) fuel cell with serpentine channels has been developed in order to investigate the sensitivity of the fuel cell performance to the anisotropic gas permeability and electrical conductivity of gas diffusion layers (GDLs). For a realistic range of transport properties being investigated, the fuel cell performance was found to be very sensitive to the electrical conductivity but almost insensitive to the gas permeability of the GDL. For the given operating conditions, the current density was found to be a maximum in the vicinity of the edge between the flow channel and the rib of the current collector. Since the most common GDL materials present a rather significant anisotropy in the in-plane directions, the effects of such anisotropy have been evaluated. Given that the through-plane conductivity is maintained constant for all the cases investigated, for a realistic range of the in-plane electrical conductivity, the fuel cell performance was found to be almost insensitive to this parameter. Therefore such anisotropy can be practically ignored. Finally, for single phase operating conditions, the U-bend in the serpentine channel has no effect on the overall performance of the fuel cell. Hence, only a straight channel of the fuel cell may be modelled and used as a quick performance indicator.

13/01780 Evaluation of high temperature gas cleaning options for biomass gasification product gas for solid oxide fuel cells

Aravind, P. V. and de Jong, W. *Progress in Energy and Combustion Science*, 2012, 38, (6), 737–764.

An analysis of high temperature gas cleaning systems for cleaning the product gas of biomass gasification for fuelling solid oxide fuel cells (SOFCs) is presented. Influence of biomass derived contaminants on SOFCs is briefly presented and the removal of potential contaminants such as tar, particulates, H₂S and HCl, alkali compounds from biosyngas is reviewed. It appears that the gasification product gas can be cleaned to meet the requirements of SOFCs based on Ni/GDC anodes at high temperatures (typically in the range of 1023–1223 K) by using currently known gas cleaning methods. Although information from literature, results from chemical equilibrium studies and preliminary experiments were sufficient to put forward a conceptual design for a high temperature gas cleaning system, detailed experimental investigations are still required. This is needed to obtain detailed information on contaminant tolerance of SOFCs, and to arrive at detailed designs of gas cleaning units that are economically viable for biomass gasifier–SOFC systems.

13/01781 Ex-situ characterisation of gas diffusion layers for proton exchange membrane fuel cells

El-kharouf, A. *et al. Journal of Power Sources*, 2012, 218, 393–404.

This paper presents the first part of a complete *ex situ* characterization of a wide range of commercial gas diffusion layers (GDLs) used in low temperature and high temperature proton exchange membrane (PEM) fuel cells. Physical and electrical characteristics of the GDLs are reported. The results show that the substrate structure has a significant effect on the mechanical and electrical properties of the GDL. Moreover, the micro porous layer (MPL) structure determines the roughness of the surface, and affects the permeability and porosity of the GDL. It was found that the substrate treatment with PTFE affects the GDL characteristics; PTFE loading increases the GDLs hydrophobicity and permeability, however, decreases its overall porosity and resistivity. Adding a MPL to the substrate, results in a decrease in porosity and permeability and an increase in resistivity. The contact resistance of the GDL and the bipolar plate increases when the GDL thickness and PTFE loading are increased. This technical paper shows a close relationship between GDL materials and their physical characteristics and highlights the importance of optimizing GDLs for fuel cell applications.

13/01782 Fabrication of copper–indium–gallium–diselenide absorber layer by quaternary-alloy nanoparticles for solar cell applications

Liu, C. P. and Chuang, C. L. *Solar Energy*, 2012, 86, (9), 2795–2801. Copper–indium–gallium–diselenide (CIGS) thin films were fabricated using precursor nanoparticle-ink and sintering technology. The precursor uses quaternary compound composition ratios of Cu/(In + Ga) = 0.95, Ga/(In + Ga) = 0.39, and Se/(Cu + In + Ga) = 0.75, respectively. The nanoparticles were fabricated by a rotary ball milling technique. After milling, the agglomerated CIGS powder to a particle size smaller than 100 nm. The nanoparticle-ink was fabricated by mixture of CIGS nanoparticles, solution, and organic polymer.

Crystallographic, morphological, stoichiometric, and photovoltaic properties of films were obtained by sintering the precursor CIGS sample in a non-vacuum environment with selenization. Analytical results indicate that the CIGS absorption layer prepared with a nanoparticle-ink polymer, through sintering, has a chalcopyrite structure and favourable compositions. In this sample, the mole ratio of Cu:In:Ga:Se is equal to 0.95:0.69:0.38:1.99, and related ratios of Ga/(In + Ga) and Cu/(In + Ga) are 0.35 and 0.89, respectively. Analysis of a performance of the obtained solar cell under standard air mass 1.5 global illumination revealed a conversion efficiency of 2.392%.

13/01783 Fuel quality issues with biogas energy – an economic analysis for a stationary fuel cell system

Papadias, D. D. *et al. Energy*, 2012, 44, (1), 257–277.

This paper reviews the information available on the impurities encountered in stationary fuel cell systems, their effects on the fuel cells, and the maximum allowable concentrations of select impurities suggested by manufacturers and researchers. A generic model of a molten carbonate fuel cell-based power plant operating on digester and landfill gas has been developed; it includes a gas processing unit, followed by a fuel cell system. The model includes the key impurity removal steps to enable predictions of impurity breakthrough, component sizing, and utility needs. These data, along with process efficiency results from the model, were subsequently used to calculate the cost of electricity. Sensitivity analyses were conducted to correlate the concentrations of key impurities in the fuel gas feedstock to the cost of electricity.

13/01784 Numerical study on carbon deposition of SOFC with unsteady state variation of porosity

Yan, M. *et al. Applied Energy*, 2012, 97, 754–762.

In order to research the failure mechanism of solid oxide fuel cell (SOFC), an unsteady state two-dimensional model that considers the carbon deposition is presented. Navier–Stokes (N–S) equations, heat transfer equation, mass transfer equation, electron and ion transport equation are solved by COMSOL 3.5. In the numerical model, with the operating temperature at 800 °C, gas phase chemical reaction kinetics is used to predict the carbon deposition molar mass. Furthermore, the unsteady state variation of anodic porosity and the electrical conductivity that caused by carbon deposition is taken into account. From the numerical results, it can be found that the effect of the variation of anodic porosity on SOFC electronic performance is about 7%. Therefore, it is necessary to consider the variation of anodic porosity when come up against carbon deposition problems of SOFC. The increased inlet water/methane ratio could eliminate carbon deposition, but the current density would decline dramatically.

13/01785 Performance optimization of the BIPV powered electrolyser and fuel cells installation

Stamenic, L. *et al. Energy and Buildings*, 2012, 51, 39–47.

A practical multipurpose implementation of hybrid renewable energy system completely located within the building and including building integrated photovoltaic (BIPV) solar power energy source is presented. The system uses solar photovoltaic electricity generated by the building skin to produce hydrogen for fuel cells, which in turn, when converted to energy in fuel cells, may be used to supply additional power to the building (or fuel cell vehicles) when solar power is not sufficient, for example at night or in periods of low insolation. Electricity generated from 8.2 kW_p BIPV array optimally supplies the electrolyser near the maximum power point level of the BIPV array. To further optimize hydrogen production, the electrolyser is connected to the local electrical utility, and DC power is provided to the electrolyser through a custom on-board DC power supply that supplements the BIPV array. Performance of the complete installation is optimized to provide continual production at the optimal efficiency level of hydrogen production at constant power. The results obtained from the system operation have shown excellent voltage and current regulation during operation of the electrolyser. The project shows the potential for development of similar building integrated hybrid systems elsewhere with possibilities for inclusion of additional renewable energy sources and added functionality.

13/01786 Quantitative analysis of carbon corrosion during fuel cell start-up and shut-down by anode purging

Linse, N. *et al. Journal of Power Sources*, 2012, 219, 240–248.

The corrosion of the carbon support during start-up and shut-down of polymer electrolyte fuel cells was systematically quantified to elucidate effects related to the propagation of the gas front through the anode compartment and to determine the influence of relevant operating parameters. Measurements with different reactant gas concentrations and gas flow rates suggest that the gas exchange process is dominated by a homogeneous displacement of the anode gas in case of start/stop operation at OCV. The influence of additional effects such as direct recombination of hydrogen and oxygen, diffusion on the channel and land scale and pseudocapacitive effects seems to be negligible under

the investigated conditions. With an external load applied during the gas exchange process (discharge mode), shut-down induced carbon corrosion strongly differs from the behaviour at OCV. The virtually constant corrosion rates obtained below a critical purge gas flow rate in the discharge mode are attributed to a significant contribution of electrochemical hydrogen consumption. Temperature and humidity variation measurements demonstrate that the carbon corrosion behaviour during real start/stop processes can differ considerably from the correlations obtained under controlled potential conditions in H_2/N_2 mode. Thus, potential cycling experiments only provide limited information about start/stop durability under application relevant conditions.

13/01787 Using cathode spacers to minimize reactor size in air cathode microbial fuel cells

Yang, Q. *et al. Bioresource Technology*, 2012, 110, 273–277.

Scaling up microbial fuel cells (MFCs) will require more compact reactor designs. Spacers can be used to minimize the reactor size without adversely affecting performance. A single 1.5 mm expanded plastic spacer (S1.5) produced a maximum power density ($973 \pm 26 \text{ mW m}^{-2}$) that was similar to that of an MFC with the cathode exposed directly to air (no spacer). However, a very thin spacer (1.3 mm) reduced power by 33%. Completely covering the air cathode with a solid plate did not eliminate power generation, indicating oxygen leakage into the reactor. The S1.5 spacer slightly increased columbic efficiencies (from 20% to 24%) as a result of reduced oxygen transfer into the system. Based on operating conditions (1000Ω , $CE = 20\%$), it was estimated that 0.9 L h^{-1} of air would be needed for 1 m^2 of cathode area suggesting active air flow may be needed for larger scale MFCs.

13/01788 Water recovery and air humidification by condensing the moisture in the outlet gas of a proton exchange membrane fuel cell stack

Wan, Z. M. *et al. Applied Thermal Engineering*, 2012, 42, 173–178.

Humidification is one of the most important factors for the operation of proton exchange membrane fuel cell (PEMFC). To maintain the membrane at hydrated state, plenty of water is needed for the state-of-the-art of PEMFC technology, especially in large power applications or long time operation. A condenser is introduced to separate liquid water from the air outlet for air self-sufficient in water of the stack in this study. The condensed temperature at the outlet of the condenser and water recovered amount for air self-sufficient in water are investigated theoretically and experimentally. It is shown that the condensed temperature for air self-sufficient in water is irrelevant with the working current of the stack. When the condenser outlet temperature was above the theoretical line, recovery water was not sufficient for the air humidification. On the contrary, it is sufficient while the temperature was below the theoretical line. It is also shown that when the moisture is sufficiently cooled, large amount water can be separated from the outlet gas, and it increased almost linearly with the time. With the introduction of the condenser, the recovered amount of water can easily satisfy the air self-sufficient in water by condensing the outlet gas to a proper temperature.

($P < 0.01$) in the group that operated the mechanical fan during 4 h per day. The average increase of the total heating energy consumption by the 4 h fan operation is 0.07 GJ m^{-2} and its energy cost is estimated at $\$1.01/\text{m}^2$ or $\$85\text{--}105$ per household over whole heating period.

13/01790 A net-zero building application and its role in exergy-aware local energy strategies for sustainability

Kilkiş, Ş. *Energy Conversion and Management*, 2012, 63, 208–217.

Based on two case studies, this paper explores the nexus of exergy, net-zero targets, and sustainable cities as a means of analysing the role of exergy-aware strategies at the building and district level. The first case study is a premier building in Ankara that is ready to meet the net-zero exergy target. It is also the first building in Turkey to receive the highest platinum rating in Leadership in Energy and Environmental Design. A net-zero exergy building (NZEXB) is a building that has an annual sum of net-zero exergy transfer across the building-district boundary. This new target is made possible by lowered annual exergy consumption (AEXC), and increased on-site production from a bundle of sustainable energy technologies. The modelled results of the building indicate that the reduced AEXC of $60 \text{ kWh m}^{-2} \text{ yr}$ is met with on-site production of $62 \text{ kWh m}^{-2} \text{ yr}$. On-site production includes PV and building integrated PV, a micro-wind turbine, combined heat and power, GSHP, and solar collectors. Diversified thermal energy storage tanks further facilitate the exergy supply to meet with the exergy demand. The results of this case study provide key lessons to structure an energy value chain that is more aware of exergy, which are up-scalable to the district level when the bundle of sustainable energy technologies is zoomed out across a larger spatial area. These key lessons are then compared with the second case study of two districts in the south heating network of the city of Stockholm, which was the European Green Capital in 2010. The levels of exergy match in these districts of Stockholm, namely the districts of Högdalen and Hammarby, is found to be 0.82 and 0.84, respectively. However, there remain several bottlenecks for these districts to reach net-zero targets at the community level. The paper concludes that the NZEXB case study has much to offer as a 'building block' to reform the way energy is converted and managed and in this way, to structure an exergy-aware energy value chain for greater sustainability in green cities of the future.

13/01791 Bioaugmentation: possible solution in the treatment of bio-refractory organic compounds (Bio-ROCs)

Semrany, S. *et al. Biochemical Engineering Journal*, 2012, 69, 75–86.

Water quality is questionable when looking at the emerging pollutants that accumulate in hydrosphere day after day. In terms of water treatments to eliminate organic compounds, biological treatments are the most used technique, especially the conventional activated sludge (CAS) process. Unfortunately, several of these compounds such as petroleum and industrial wastes, some pesticides, pharmaceuticals, and hormonal substances appear to be refractory to such treatments and can join the different water surfaces from other natural environments especially contaminated soils. Physical and chemical treatments, in particular the advanced oxidation processes (AOPs) are able to degrade some of these pollutants, but the nature and the possible effects of oxidation by-products remain controversial when complete mineralization does not occur. The aim of this article is to shed light on new and renewed biotechnological techniques recently introduced to resolve recalcitrance problem. Amending activated sludge with additional microorganisms able to produce versatile enzymes to enhance biodegradability or 'bioaugmentation', is gradually considered as a possible solution for the recalcitrance of bio-refractory organic compounds (Bio-ROCs). The use of this technique, traditionally in soil remediation field, and recently in water and sediments treatment is reviewed in this paper.

13/01792 Combined effect of two local discomfort parameters studied with a thermal manikin and human subjects

Barna, E. and Bánhidi, L. *Energy and Buildings*, 2012, 51, 234–241.

Nowadays designers have to create energy efficient systems. Besides, they have to provide thermally comfortable environments for occupants. These, sometimes conflicting requirements lead to the development of such systems like surface heating and cooling systems that affect occupant's heat exchange with his surroundings via radiation. With regards to the above-described systems, combined effect of two local discomfort parameters is studied in this paper, namely radiant temperature asymmetry and warm floors. The European standard CR 1752 deals with these parameters separately and no data are available on how many people are dissatisfied due to combined exposures. The paper summarizes the results of climate chamber experiments conducted with a thermal manikin as well as human subjects that were exposed to cold wall and warm floor simultaneously present. The results show that equivalent homogenous temperature of the manikin decreased by 2°C at the hands and face due to the cold radiating surface regardless of the warm floor. It was found that the

15 ENVIRONMENT

Pollution, health protection, applications

13/01789 A field study of occupant behavior and energy consumption in apartments with mechanical ventilation

Park, J. S. and Kim, H. J. *Energy and Buildings*, 2012, 50, 19–25.

The purpose of this field study was to evaluate the ventilation practices of occupants and corresponding heating energy consumption in mechanically ventilated apartments, using airflow measurements, energy data collection, and occupant questionnaire. A sample of 139 apartments was selected for the field study from an apartment complex located in south metropolitan area of Seoul, Korea. About 68% (95 of 139) did not use mechanical fans for ventilation at all during the heating period and 58% of 95 responders cited elevated heating energy costs as the primary reason for not using the mechanical ventilation fan. Among the occupants who intermittently used the mechanical fans in their apartments (32%), the average operation time was less than 2 h per day. Total heating energy consumption is increased about 32% ($P < 0.05$) when the mechanical fan is operated during 4 h per day. Occupants' acceptability of the indoor air is also significantly improved

thermal sensation and skin temperatures of human subjects were affected more by the radiation from the vertical cold surface than by the warm floor. Furthermore, genders showed significant differences regarding skin temperature change during sessions.

13/01793 Comparison of potentially toxic metals leaching from weathered rocks at a closed mine site between laboratory columns and field observation

Villafane, O. R. S. *et al. Applied Geochemistry*, 2012, 27, (12), 2271–2279.

Potentially toxic metals, such as Cu, Pb and Zn, are leached from weathered rocks at many closed mine sites due to the acidic environments and mineralogical modifications. The mobilized toxic metals may cause contamination of surrounding water bodies. In this study, both laboratory column experiments and field observations at a former mine located in the north of Japan were carried out to compare the leaching behaviour of Cu, Pb and Zn. The thickness of the surface weathered rock was varied (10, 20 and 30 cm) for the columns experiments while porous cups for porewater sampling were set up at different depths (GL-15, GL-45, GL-70, and GL-95 cm) for the field observations. Deionized water was added once a week over 75 weeks to the columns to simulate rainfall while porewater was extracted by a vacuum pump in several sampling campaigns (over 18 months). Similar low pH and leaching behaviour of potentially toxic metals were observed for column experiments and field observations. A moderate increase in concentration with depth was observed for Cu and Zn. However, no increase in concentration was observed for Pb. This suggests that the leaching of Cu and Zn is enhanced by the length of the flow pathway through the weathered rock layer while Pb concentration is restricted by the precipitation of insoluble Pb sulfate. Thus, the thickness of the weathered rock layer is an important parameter that should be taken into consideration to estimate the loads of some potentially toxic metals, which is important when designing remediation schemes.

13/01794 Conversion of biomass from an invasive species into activated carbons for removal of nitrate from wastewater

Nunell, G. V. *et al. Biomass and Bioenergy*, 2012, 44, 87–95.

Development of activated carbons targeted at nitrate ion removal is investigated by chemical activation of sawdust from the invasive species *Parkinsonia aculeata* wood. Phosphoric acid and potassium hydroxide are comparatively used as activating agent. Its effect on main physicochemical properties and on the effectiveness of the activated carbons in nitrate removal is compared with those determined for a commercial sample. Activated carbons developed with the base show the best effectiveness in nitrate removal, as determined from application of the Langmuir model to the experimental isotherms. The behaviour is consistent with the development of surface basic groups and the more basic character of these carbons. Noticeable improvement in nitrate uptake for all the carbons is attained after treatment with a saturated urea solution, with removal levels of ~80–90%, despite reductions in porous structures. Nitrate adsorption onto the urea-treated carbons is in direct correlation with their enhanced contents of elemental nitrogen.

13/01795 Decomposition of biogas residues in soil and their effects on microbial growth kinetics and enzyme activities

Chen, R. *et al. Biomass and Bioenergy*, 2012, 45, 221–229.

The rapid development of biogas production will result in increased use of biogas residues as organic fertilizers. However, control of microbial activity by organic fertilizers remains a challenge for modern land use, especially with respect to mitigating greenhouse effects and increasing C sequestration in soil. To address this issue, the authors compared CO₂ emissions, microbial growth and extracellular enzyme activities in agricultural soil amended with biogas residues (BGR) versus maize straw (MST). Over a 21-day incubation period, 6.4% of organic C added was mineralized and evolved as CO₂ with BGR and 30% with MST. As shown by the substrate-induced growth respiration approach, BGR and MST significantly decreased the specific microbial growth rate (μ) and increased the microbial biomass C in the soil, indicating a clear shift in the microbial community to slower-growing microorganisms. Because of the reduced availability of C associated with the less labile C and more lignin in biogas residues, observed μ values and microbial biomass C were lower after BGR application than after MST application. After 21 days' incubation, BGR had no effect on the activity of three extracellular enzymes: β -glucosidase and cellobiohydrolase, both of which are involved in cellulose decomposition; and xylanase, which is involved in hemicellulose decomposition. In contrast, MST significantly increased the activity of these three enzymes. The application of biogas residues in short-term experiment leads to a 34% increase in soil C content and slower C turnover as compared to common maize residues.

13/01796 Decomposition of the environmental inefficiency of the meta-frontier with undesirable output

Chiu, C.-R. *et al. Energy Economics*, 2012, 34, (5), 1392–1399.

This study presents an alternative analysis framework to evaluate the effects of technology heterogeneities and undesirable output on environmental efficiency measurement. The proposed framework combines the directional distance function and a meta-frontier analysis. It can be used to measure efficiency improvements brought about by enhanced technical management and technological advances. For demonstration purposes, the authors used the framework to measure the environmental efficiency in 90 countries worldwide for the 2003–2007 period. The results showed that when the meta-technology set is used as the evaluation basis, the average environmental efficiency of high competitiveness countries is greater than that of lower-middle, low, and upper-middle competitiveness countries. The upper-middle competitiveness countries perform worse than the lower-middle and low competitiveness countries because of the excessive labour force usage and carbon dioxide emissions in these countries. It was also found that the environmental inefficiency of the meta-frontier for high competitiveness countries can be attributed to managerial failure in the production process, whereas that for upper-middle, lower-middle, and low competitiveness countries can be attributed to technological differences.

13/01797 Does generation form influence environmental efficiency performance? An analysis of China's power system

Xie, B.-C. *et al. Applied Energy*, 2012, 96, 261–271.

To achieve sustainable development, the focus on power system efficiency should move from analysis of just economic benefits to environmental efficiency studies that assess both economic benefits and carbon emissions. Therefore, balancing the development of different generation forms is a critical field in improving environmental efficiency. Here the authors classify the 30 provincial administrative regions in China into three categories according to the proportion of thermal power ratio. They then use a two-stage environmental network DEA model to compare their efficiency performance. Analysis of the evaluation results leads to the following conclusions. Generation forms have a significant influence on the environmental efficiency performance of power systems, but the differences vary greatly according to the power supply and demand situation. The policy to incentivize clean energy development has achieved its objective in the generation division and further policy reforms should be extended to the grid division. A more flexible power development plan should be implemented according to regional resources endowment for better planning of power system development on a national basis.

13/01798 Fast evolution of urban ultrafine particles: implications for deposition doses in the human respiratory system

Manigrasso, M. and Avino, P. *Atmospheric Environment*, 2012, 51, 116–123.

The impact of ultrafine particles (UFP) (diameters < 100 nm) on human health has been addressed in many toxicological studies. It is therefore important to assess relevant respiratory exposure of the population. In this paper, aerosol number-size distribution was measured with 1 s time resolution, in a street canyon, in proximity to traffic, with the purpose of studying the fast evolution of UFP doses deposited in the respiratory system. Close to the traffic, nucleation particle concentrations increase within few seconds and decrease in tens of seconds. As a consequence, the exposure pattern, near to traffic, may be represented as a sequence of short-term peak exposures. The number of UFPs deposited for each tidal volume of air inhaled (instant UFP doses) rapidly reaches level of 10⁷ particles, with maximum values for the alveolar interstitial region. For the correct estimate of short-term exposures, in scenarios involving proximity to traffic, it is therefore crucial to rely on aerosol measurements with a time resolution able to trace the fast evolution of aerosol from vehicle exhausts. When traffic levels drop, spike values of instant UFP doses are comparatively less frequent and the maxima of their size distributions shift from 10 to 20 nm (nucleation particles) to greater diameter (up to about 60 nm).

13/01799 Global warming and electricity demand in the rapidly growing city of Delhi: a semi-parametric variable coefficient approach

Gupta, E. *Energy Economics*, 2012, 34, (5), 1407–1421.

This paper estimates the climate sensitivity of electricity demand in Delhi, India using daily data on electricity demand and apparent temperature for the period 2000–2009. The study adopts a semi-parametric variable coefficient model in order to investigate the impact of climatic factors on electricity demand. As evident from previous studies, electricity demand is a U-shaped function of temperature. The authors find the rising part of the temperature–electricity curve to become more pronounced over time implying an increase in cooling

demand per unit increase in summer temperatures. The study therefore predicts the adverse effects of climate change on electricity demand to be asymmetrically distributed in different seasons in the future, resulting in a serious disequilibrium in the hot months.

13/01800 Homeowners' preferences for adopting innovative residential heating systems: a discrete choice analysis for Germany

Michelsen, C. C. and Madlener, R. *Energy Economics*, 2012, 34, (5), 1271–1283.

Space heating accounts for a large fraction of the primary energy consumption and CO₂ emissions of residential buildings in Germany. Besides targeting the insulation standard, innovative (i.e. renewable energies-based and/or energy-efficient) residential heating systems (RHS) offer the potential to reduce CO₂ emissions from space heating. Therefore, understanding the determinants of the RHS adoption decision becomes increasingly important. This paper analyses the influence of preferences about RHS-specific attributes on the homeowners' adoption decision. Moreover, the authors control for the influence of socio-demographic, home and spatial characteristics. To this end, the discrete appliance choice is specified by a multinomial logit model and applied to representative survey data for Germany. The findings show that there are different drivers for the adoption of innovative RHS (partly) based on renewable energies in newly built and existing one- and two-family homes, and that the importance of key drivers also differs across groups of homeowners and RHS, respectively. First, it was found that adopters of a gas- and oil-fired condensing boiler with solar thermal support have a strong preference for energy savings, while adopters of a heat pump or wood pellet-fired boiler prefer being more independent from fossil fuels. Second, owners of existing homes were found to have less scope for preferences in the RHS adoption decision. The decision to replace a RHS in an existing home is rather driven by socio-demographic, home and spatial characteristics. Third, the findings are quite contrary for newly built homes. Here, preferences about RHS specific attributes are found to be highly relevant, while there is less evidence for an influence of socio-demographic, home and spatial characteristics on the adoption decision.

13/01801 Impact of climate change on building energy use in different climate zones and mitigation and adaptation implications

Wan, K. K. W. *et al. Applied Energy*, 2012, 97, 274–282.

Impact of climate change on energy use in office buildings in a city within each of the five major architectural climates across China – Harbin (severe cold), Beijing (cold), Shanghai (hot summer and cold winter), Kunming (mild) and Hong Kong (hot summer and warm winter) – was investigated for two emissions scenarios. For low forcing, the estimated increase in cooling energy use was 18.5% in Harbin, 20.4% in Beijing, 11.4% in Shanghai, 24.2% in Kunming and 14.1% in Hong Kong; and the reduction in heating 22.3% in Harbin, 26.6% in Beijing, 55.7% in Shanghai, 13.8% in Kunming and 23.6% in Hong Kong. Space heating is usually provided by oil- or gas-fired boiler plants, whereas space cooling mainly relies on electricity. There would certainly be a shift towards electrical power demand. More energy use in buildings would lead to larger emissions, which in turn would exacerbate climate change and global warming. Energy conservation measures were considered to mitigate the impact of climate change on building energy use. These included building envelope, indoor condition, lighting load density and chiller coefficient of performance. It was found that raising the summer indoor design condition by 1–2 °C could result in significant energy savings and have great mitigation potential.

13/01802 Impacts of climate change on building heating and cooling energy patterns in California

Xu, P. *et al. Energy*, 2012, 44, (1), 792–804.

Global climate change is making California's mild Mediterranean climate significantly warmer, and a substantial impact on building energy usage is anticipated. Studies on building cooling and energy demand have been inaccurate and insufficient regarding the impacts of climate change on the peak load pattern shifts of different kinds of buildings. This study utilized archived general circulation model projections and statistically downscaled these data to the site scale for use in building cooling and heating simulations. Building energy usage was projected out to the years of 2040, 2070, and 2100. This study found that under the condition that the cooling technology stays at the same level in the future, electricity use for cooling will increase by 50% over the next 100 years in certain areas of California under the Intergovernmental Panel on Climate Change (IPCC)'s worst-case carbon emission scenario, A1F1. Under the IPCC's most likely carbon emission scenario (A2), cooling electricity usage will increase by about 25%. Certain types of buildings will be more sensitive to climate change than others. The aggregated energy consumption of all buildings including both heating and cooling will only increase slightly.

13/01803 Improving policy instruments to better tap into homeowner refurbishment potential: lessons learned from a case study in Germany

Weiss, J. *et al. Energy Policy*, 2012, 44, 406–415.

Increasing energy efficiency in residential dwellings remains one of the top climate protection priorities in many European countries. In Germany regulatory instruments and subsidy programmes, together with communicative instruments, represent the most important measures for motivating homeowners to pursue energy-efficient retrofitting – to date, however, with little success; a tremendous potential for energy savings still exists particularly in the category of single-family houses. The present article primarily addresses the question of how to improve or supplement the political instruments in order to increase refurbishment rates and tap these potential savings; it presents the results of an analysis of existing policy instruments in Germany focusing on the most promising types of building and refurbishment measures that also takes into account the barriers responsible for the discrepancy between potential and actual refurbishment rates. It is shown that consideration of the specific peculiarities and situations homeowners face, coupled with an analysis of the energy saving potentials of their buildings, offers valuable insights and is critical for evaluating policy instruments and finding the mix of instruments that will purposefully encourage the most effective refurbishment measures. Drawing on these results, recommendations for the improvement of current policy instruments and implementation of new instruments are provided.

13/01804 Measurement and quantitative analysis of radioactivity concentration in soil on playgrounds of Korean elementary schools

Kim, M.-H. *et al. Annals of Nuclear Energy*, 2012, 47, 21–27.

The aim of this study is to obtain Korean nationwide basic data on the distribution of environmental radiation and radioactivity in normal times and to draw a comparison of chart characteristics and distribution in various areas for contributing to the improvement in radioactivity analysis technology, people's health and national environment in the future. Soil sampling points from 160 elementary schools were selected based on the division of the Korean Peninsula by area before samples of soil were taken on playgrounds of the selected schools for analysis. The soil radioactivity concentrations in the investigated areas were measured by means of high purity Ge (HPGe) detector. The results obtained show that K-40 (potassium-40) value ranged from 654.49 ± 365.05 Bq/kg in Jeju Island to 1287.00 ± 299.81 Bq/kg in Incheon Metropolitan City, Cs-137 (caesium-137) value ranged from 0.819 ± 0.164 Bq/kg in North Jeolla Province to 0.140 ± 0.080 Bq/kg in Ulsan Metropolitan City, Be-7 (beryllium-7) value ranged from 979.5 ± 123.22 Bq/kg in Seoul Metropolitan City to 11.81 ± 3.29 Bq/kg in South Jeolla Province, Th-208 (thorium C) value ranged from 90.82 ± 14.66 Bq/kg in Incheon Metropolitan City to 24.03 ± 8.25 Bq/kg in Busan Metropolitan City, Pb-212 (thorium B) value ranged from 91.99 ± 25.94 Bq/kg in Incheon Metropolitan City to 25.23 ± 18.11 Bq/kg in Busan Metropolitan City, Bi-214 (radium C) value ranged from 42.70 ± 16.79 Bq/kg in Incheon Metropolitan City to 14.79 ± 10.30 Bq/kg in Jeju Island, Ra-226 (radium-226) value ranged from 96.63 ± 32.12 Bq/kg in Incheon Metropolitan City to 36.77 ± 9.30 Bq/kg in Busan Metropolitan City.

13/01805 Measuring social welfare, energy and inequality in Germany

Schlör, H. *et al. Applied Energy*, 2012, 97, 135–142.

This analysis shows that the Atkinson index provides a powerful tool not only to measure the distribution of income but also as a new tool to estimate the distributional dimensions of energy consumption. This analysis has shown that a distribution analysis based on the Atkinson index can make an important contribution to the social debate about the distributional justice of income and consumption. With the epsilon parameter, the Atkinson index explicitly reveals the inequality aversion of society, and this enables us to define how sensitively the Atkinson index should react to inequalities. This parameter expresses the assessment on the part of society of its own vulnerability. The more acutely society sees its vulnerability through unequal distribution of income and consumption the higher is epsilon. This self-perception of society determines the value of epsilon (0.1–2.0). Every society is affected by this vulnerability, which could be reduced by a sustainable development of society. For the purposes of sustainable development, epsilon can be interpreted as a sustainable parameter. The transfer of money represented by epsilon can be used to finance sustainable projects, which are not part of the social welfare function. Epsilon can be extended with a view to sustainable development in such a way that the greater the epsilon value is, the higher the need for financing sustainable development projects is in the view of society. The transfer losses can then be used for sustainable measures and thereby generate intergenerational profits for future generations. Epsilon can therefore be interpreted as an intergenerational justice factor in the sense of sustainable development. A low epsilon value means that society has a

low aversion to inequality both in an intragenerational and an intergenerational sense. The aversion increases with a rising epsilon, and society takes more intra- and intergenerational questions into consideration. The trade-off between equality and efficiency is thereby extended to the area of intergenerational equality. These distributional effects are of great political interest not only in Germany but also in the European Union and in the OECD as recent studies by these organizations show.

13/01806 Minimizing the thermal impact of computing equipment upgrades in data centers

Siriwardana, J. *et al. Energy and Buildings*, 2012, 50, 81–92.
Upgrading of today's air-cooled data centres (DCs) with high-performance computing, networking, and storage equipment is a challenging task due to typically higher power needs and more adverse cooling requirements of new equipment. To cope with the increase of the power and heat load in DCs, load spreading is commonly applied. This technique distributes the thermal load of new equipment over multiple racks if the power requirement and heat generation of new equipment exceeds the rack's capacity. The authors present a novel load spreading technique that allows upgrading of the computing equipment with minimal thermal impact on the existing optimized DC cooling environment. This approach is based on an abstract heat-flow model of the DC, whose parameters are determined by performing a measurement campaign in the DC and with support of computational fluid dynamics simulations. The optimum placement of the new equipment in the racks of the DC is found by applying a particle swarm optimization technique to this model. The effectiveness of this method was assessed based on experiments performed in a production DC. The results show that this holistic approach for optimizing the placement of the upgraded computing equipment in the DC outperforms the conventional load spreading technique.

13/01807 Modeling the exergy behavior of human body

Mady, C. E. K. *et al. Energy*, 2012, 45, (1), 546–553.
Exergy analysis is applied to assess the energy conversion processes that take place in the human body, aiming at developing indicators of health and performance based on the concepts of exergy destroyed rate and exergy efficiency. The thermal behaviour of the human body is simulated by a model composed of 15 cylinders with elliptical cross section representing: head, neck, trunk, arms, forearms, hands, thighs, legs and feet. For each, a combination of tissues is considered. The energy equation is solved for each cylinder, being possible to obtain transitory response from the body due to a variation in environmental conditions. With this model, it is possible to obtain heat and mass flow rates to the environment due to radiation, convection, evaporation and respiration. The exergy balances provide the exergy variation due to heat and mass exchange over the body, and the exergy variation over time for each compartments tissue and blood, the sum of which leads to the total variation of the body. Results indicate that exergy destroyed and exergy efficiency decrease over lifespan and the human body is more efficient and destroys less exergy in lower relative humidities and higher temperatures.

13/01808 Patterns of occupant interaction with window blinds: a literature review

Van Den Wymelenberg, K. *Energy and Buildings*, 2012, 51, 165–176.
There is no comprehensive consensus about the way people operate blinds or the motivating factors that influence their decisions. However, there is a substantial body of research, encompassing data from more than 50 buildings worldwide that offers guidance. Patterns of blind use can affect the energy consumption of buildings substantially and therefore energy and daylighting simulations that do not account properly for these blind use patterns will have greater error. An outline for a new more nuanced model for simulation-based blind control is offered. Specifically, this paper reviews the energy implications of blind use, blind occlusion and rate of change from field studies, specific quantitative measures influencing user blind control, investigations into user acceptance of automated blind control, and finally conclusions and knowledge gaps are summarized and suggested next steps for research are provided. Addressing these gaps is critical for the continued progress of the energy efficiency movement.

13/01809 Quantification of gains and risks of static thermal rating based on typical meteorological year

Heckenbergerová, J. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 227–235.
The growing demand for electricity and the restructuring of power markets is forcing the power industry to change the way that power systems are planned and operated. Traditionally, transmission lines have been operated based on fixed deterministic thermal ratings, causing underutilization of their potential capacity. Efforts to overcome this limitation led to the development of alternative rating strategies based on probabilistic and dynamic methods. In this paper, a probabilistic static thermal rating method based on typical weather

conditions along a transmission line is described and analysed. The results of load and energy throughput analyses show that the use of this rating approach can significantly increase line throughput compared to traditional deterministic rating methods. However, this approach can also substantially increase the risk of thermal overload. To identify the problems associated with the use of a probabilistic static thermal rating method, the authors performed a sensitivity study. Statistical analysis of weather parameters shows that line ratings calculated from typical weather data are inflated. Additional results confirm that values of risk tolerance and wind direction incorporated into the rating method significantly affect the resulting rating values. The authors suggest values for these parameters that minimize the risk of line overloading.

13/01810 Selection of climatic variables and time scales for future weather preparation in building heating and cooling energy predictions

Chen, D. *et al. Energy and Buildings*, 2012, 51, 223–233.
The effects of future weather preparation using mean changes in different climatic variables at different time scales on residential building heating and cooling energy requirement predictions were investigated using dynamic building simulations. It was found that the predicted reductions in heating energy requirement obtained using any two future weather data sets are likely to be within or around 10% difference from each other if the future weather preparation incorporates at least the changes in the mean air temperatures. For cooling energy requirement predictions in temperate and hot climates, it is recommended to use future weather data prepared with the changes in at least two climatic variables, namely air temperature and humidity. However, for cooling energy requirement predictions in relatively cold climates, future weather preparation should consider the changes in mean monthly or seasonal climatic variables including at least air temperature, solar irradiance and humidity. Alternatively, changes in at least the mean monthly air temperature, daily maximum/minimum temperatures and humidity should be used. The cooling energy requirement predictions obtained using any two future weather data prepared with these recommended climatic variable sets are likely to be within or around 10% difference from each other.

13/01811 Siting locally-unwanted facilities: what can be learnt from the location of Italian power plants

Garrone, P. and Groppi, A. *Energy Policy*, 2012, 45, 176–186.
The reaction of communities to the development of energy facilities is based on the environmental impact of the investment, but it also reflects the *ex ante* propensity of residents to engage in collective actions. This work examined the requests of authorization of Italian power producers for new thermal plants with the purpose of testing the efficiency of market-based siting policies. The classical location factors, e.g. infrastructure availability, have been confirmed to play a role, and there is weak evidence that authorization demands have targeted communities that suffer less environmental damage. However the findings have also revealed that power producers are likely to avoid potentially suitable sites if they host a highly activist community. The paper also discusses some modifications concerning siting policies that could improve the alignment between community responses and the environmental costs of new energy facilities.

13/01812 Social groups and CO₂ emissions in Spanish households

Duarte, R. *et al. Energy Policy*, 2012, 44, 441–450.
This paper examines the social factors that underlie the composition of final demand and, therefore, determine the final volume of emissions. The study throws light on the relationships between the parameters characterizing Spanish households (income, urban/rural residence, local population density, head of household's level of education and social class) and their behaviour with regard to consumption and the demand for goods and services. On this basis, the authors determine which consumption patterns are best aligned with sustainable growth and development. The main conclusion is that the factors analysed determine the volume of emissions for each household in terms of their correlation with income, which is the primary determinant of consumption patterns. The methodology proposed combines linear social accounting models and econometric estimation of emissions elasticity with respect to spending.

13/01813 Solar assisted absorption cooling cycles for reduction of global warming: a multi-objective optimization approach

Gebreslassie, B. H. *et al. Solar Energy*, 2012, 86, (7), 2083–2094.
This work addresses the use of absorption cycles combined with solar energy for reducing greenhouse gas (GHG) emissions in the cooling sector. The problem of satisfying a given cooling demand at minimum cost and environmental impact is formulated as a bi-criterion non-linear optimization problem that seeks to minimize the total cost of the cooling application and its contribution to global warming. The latter metric, which is assessed following the principles of life cycle

assessment (LCA), accounts for the impact caused during the construction and operation of the system. The concept of Pareto optimality is employed to discuss different alternatives for reducing the contribution to global warming that differ in their economic and environmental performance. In addition, the authors analyse the effect of taxes on CO₂ on the economic and environmental performance of the system. The capabilities of the proposed approach are illustrated through a case study that addresses the design of a solar-assisted ammonia–water single-effect absorption cooling system with 100 kW of cooling capacity considering Barcelona, Spain weather conditions. The authors show that reducing the contribution to global warming considering the current energy prices and taxes on CO₂ emissions is technically viable but economically not appealing. The authors also discuss the conditions under which reducing the CO₂ emissions could become economically attractive.

13/01814 Towards improved bottom-up inventories of methane from the European land surface

Grunwald, D. *et al. Atmospheric Environment*, 2012, 51, 203–211.

Forests and wetlands are generally seen as opposites in the methane cycle of terrestrial ecosystems. Wetlands are sources for atmospheric methane and forest soils sinks. However, this greenhouse gas is also emitted by wet forest soils, which is commonly disregarded due to lacking information on their spatial distribution. Here, the authors estimated the potential bias made for the European methane budget of terrestrial ecosystems when neglecting wet forest ecosystems but including rice paddies and latest estimates for lakes. They appointed distinct annual methane rates for individual land use types based on a literature survey and weighted them according to their European area. This was performed separately for four major ecozones (cold, temperate, continental and Mediterranean). Three approaches were applied: (1) the mean values for forests and wetlands were calculated in three different scenarios, (2) assuming that boreal needle-leaved evergreen forest with a low tree cover (<40%) is predominately forested wetland (3) assuming different shares of wet forest ecosystems in individual forest areas. For the net balance 2.8 Tg CH₄–C a^{–1} were calculated which includes emissions from rice paddies (0.2 Tg CH₄–C a^{–1}) and from lakes (2.5 Tg CH₄–C a^{–1}). The different approaches for the net balances that included wet forest ecosystems mainly ranged between 4.6 and 6.7 Tg CH₄–C a^{–1}. The results suggest that wet forest ecosystems are approximately as important as wetlands for the European methane balance. European bottom-up inventories are improved best by more accurate mapping of wetlands both within and outside forests and more flux data for lakes and continental wetlands.

CO₂, NO_x, SO₂ and particulate emissions

13/01815 A feasible process for simultaneous removal of CO₂, SO₂ and NO_x in the cement industry by NH₃ scrubbing

Dong, R. *et al. Applied Energy*, 2012, 97, 185–191.

With the rapid economic and industrial development, the concentration of carbon dioxide in the atmosphere is increasing enormously, which has greatly affected the global climate and human living environment. At present, a lot of technologies have been applied to CO₂ removal in fossil fuel-fired power plants, which are one of the main CO₂ emission sources. But few researches have been done in the cement industry, which is the third largest CO₂ emission source. There is no mature technology of CO₂ removal in cement industry mentioned before. This paper proposes a feasible process for simultaneous removal of CO₂, SO₂ and NO_x in the cement industry by NH₃ scrubbing. As there is no ready steam source for the regeneration of CO₂-rich loading solvent after absorption, a process with the final product of ammonium bicarbonate is developed. With the oxidative additive of NaClO₂ added in the aqueous ammonium absorbent, the simultaneous removal of CO₂, SO₂ and NO_x is feasible by NH₃ scrubbing. The products of the process are mainly ammonium bicarbonate, ammonium sulfate and ammonium nitrate, which are all good fertilizers for crops and plants. The crystallization of NH₄HCO₃ is easier for storage and transportation than that for liquid carbon dioxide, which becomes more stable when dicyandiamide is added. The thermodynamic analysis proves that the proposed process has the advantages of energy conservation and high thermodynamic perfection degree compared with the traditional ones.

13/01816 Black carbon emissions from on-road vehicles in China, 1990–2030

Song, W. W. *et al. Atmospheric Environment*, 2012, 51, 320–328.

The rapid increase of the vehicle population makes the transport sector a significant contributor to China's black carbon (BC) emissions. This study developed an inventory to estimate emissions, reductions, and projections of BC from on-road vehicles. Total emissions of on-road vehicles were 15.0 Gg in 1990 and 64.0 Gg in 2009. Diesel vehicles were the biggest contributor, emitting 83%–95% of total emissions. Results of provincial-level analysis showed that Guangdong, Shandong and Hebei had higher emissions than other provinces. Emission standards introduced by the government to reduce particulate matter (PM) resulted in decreased BC emissions. Total reductions were up to 375.8 Gg in the period of 1999–2009, equivalent to 270 Tg CO₂ (100-year). Projections show that emissions continue to decline from 2010 but start to increase from 2015 under a business-as-usual scenario. If EURO V/VI emission standards are implemented, emissions will decline steadily until 2025. Further reductions of BC can be achieved by using biodiesel and low-sulfur fuels.

13/01817 Comparative study of regulated and unregulated toxic emissions characteristics from a spark ignition direct injection light-duty vehicle fueled with gasoline and liquid phase LPG (liquefied petroleum gas)

Myung, C.-L. *et al. Energy*, 2012, 44, (1), 189–196.

In this study, to evaluate the potential of a dedicated liquefied petroleum gas-direct injection (LPG-DI) vehicle, regulated and unregulated emissions from a light-duty gasoline direct injection (GDI) vehicle were compared. The vehicle tests were performed on a chassis dynamometer with constant volume sampler (CVS) over the federal test procedure (FTP)-75, highway fuel economy test (HWFET), and new European driving cycle (NEDC), which include the engine starting, transient and warm-up operation. The emissions of total hydrocarbon (THC) as well as nitrogen oxides (NO_x) and nanoparticles from the LPG-DI vehicle showed significantly superior performance relative to gasoline with excellent gaseous mixture preparation and low carbon fuel. The CO₂ emission of the LPG-DI vehicle decreased approximately 4–6% compared to the GDI vehicle. Aldehydes formation was influenced by vehicle test modes, such as the proportions of vehicle low speed patterns as well as long idle duration and the inclusion of engine warm-up periods. Formaldehyde, acetaldehyde, and acrolein compounds significantly increased with the LPG-DI vehicle, and this increase was related with partial oxidation during the combustion process of butane and propane. Except for the slightly increase in the HWFET mode, strong decreases in BTEX were observed with the application of LPG fuel in the FTP-75 and NEDC mode. It was found that the regulated and unregulated emissions were closely related to both the vehicle driving patterns and fuel compositions.

13/01818 Costs and potentials of reducing CO₂ emissions in the UK domestic stock from a systems perspective

Kesicki, F. *Energy and Buildings*, 2012, 51, 203–211.

In the context of ambitious commitments to reduce CO₂ emissions in industrialized countries, the domestic sector will play a crucial role as one of the biggest sources of end-use emissions. In the past, several studies have aimed to analyse the costs and the technical feasibility of CO₂ emissions reduction in the domestic stock. This paper addresses the issue of abatement costs and potentials in the housing stock from a systems perspective in order to capture interactions and interdependencies with the wider energy system. Marginal abatement cost (MAC) curves for the UK residential sector are derived based on the energy systems model UK MARKAL in combination with decomposition analysis. The results indicate that it is cost-effective to implement conservation measures, as well as increase the share of district heat and biomass for space and water heating. The decarbonization of electricity and heat dominates the lower part of the residential sector MAC curve up to £50/t CO₂. The MAC curve is found to be robust to fossil fuel prices, while more expensive electricity and limited availability of biomass significantly reduce the abatement potential. The results underline the need to assess emissions reduction from a systems perspective to capture system-wide interactions.

13/01819 Decoupling economic growth from carbon dioxide emissions: a decomposition analysis of Italian energy consumption

Andreoni, V. and Galmarini, S. *Energy*, 2012, 44, (1), 682–691.

Decomposition analysis is used to assess the progress in decoupling Italian economic growth from CO₂ emissions. The study refers to the period 1998–2006, split into two time intervals (1998–2002 and 2002–2006) and considers four explanatory factors: CO₂ intensity, energy intensity, structural changes and economic activity. The importance of sectoral dimension is taken into account by dividing the Italian economy into five main sectors: the agricultural; the industrial; the electricity and heat production, water and gas; the transport and the services sectors. An industrial sub-sector decomposition analysis is also performed by considering six industrial branches. It is found that, during the period considered, the Italian economy did not perform

absolute decoupling in terms of energy consumption and carbon dioxide emissions and that economic growth and energy intensity are the largest contributors to CO₂ emissions increase.

13/01820 Dynamic soft sensors for NO_x emissions in a circulating fluidized bed boiler

Liukkonen, M. *et al. Applied Energy*, 2012, 97, 483–490.

Fuel flexibility and the ability to burn low-grade fuels are major advantages generally associated with fluidized bed combustion. The use of demanding heterogeneous fuels such as biomass, however, not only increases the need for monitoring the dynamics of the process but also complicates the development of new methods for diagnosing and monitoring it. Soft sensors can provide a tool for supporting or replacing potentially difficult and expensive measurements or, alternatively, for predicting the behaviour of a process in the future. This paper presents an adaptive soft sensor that utilizes real plant data and makes it possible to estimate the nitrogen oxide content of flue gas in a CFB boiler fired by demolition wood. The main findings indicate on one hand that an adaptive approach is necessary to learn the dynamics of the process and on the other hand that both the linear and non-linear soft sensors perform well in this case.

13/01821 European CO₂ emission trends: a decomposition analysis for water and aviation transport sectors

Andreoni, V. and Galmarini, S. *Energy*, 2012, 45, (1), 595–602.

A decomposition analysis is used to investigate the main factors influencing the CO₂ emissions of European transport activities for the period 2001–2008. The decomposition method has been used to investigate the carbon dioxide emissions intensity, the energy intensity, the structural changes and the economy activity growth effects for the water and the aviation transport sectors. The analysis is based on Eurostat data and results are presented for 14 member states, Norway and the 27 European Union member states (EU27). Results indicate that economic growth has been the main factor behind the carbon dioxide emissions increase in EU27 both for water and aviation transport activities.

13/01822 Income inequality and carbon dioxide emissions: the case of Chinese urban households

Golley, J. and Meng, X. *Energy Economics*, 2012, 34, (6), 1864–1872.

This paper draws on Chinese survey data to investigate variations in carbon dioxide emissions across households with different income levels. Rich households generate more emissions per capita than poor households via both their direct energy consumption and their higher expenditure on goods and services that use energy as an intermediate input. An econometric analysis confirms a positive relationship between emissions and income and establishes a slightly increasing marginal propensity to emit over the relevant income range. The redistribution of income from rich to poor households is therefore shown to reduce aggregate household emissions, suggesting that the twin pursuits of reducing inequality and emissions can be achieved in tandem.

13/01823 Novel mixed matrix membranes for sulfur removal and for fuel cell applications

Lin, L. *et al. Journal of Power Sources*, 2012, 220, 138–146.

Sulfur removal is significant for fuels used as hydrogen source for fuel cell applications and to avoid sulfur poisoning of therein used catalysts. Novel mixed matrix membranes (MMMs) with well-defined transport channels are proposed for sulfur removal. MMMs are fabricated using polyimide (PI) as matrix material and Y zeolites as adsorptive functional materials. The influence of architecture conditions on the morphology transition from finger-like to sponge-like structure and the 'short circuit' effect are investigated. The adsorption and regeneration behaviour of MMMs is discussed, combining the detailed analysis of FT-IR, morphology, XPS, XRD and thermal properties of MMMs, the process-structure-function relationship is obtained. The results show that the functional zeolites are incorporated into three-dimensional network and the adsorption capacity of MMMs comes to 8.6 and 9.5 mg S g⁻¹ for thiophene and dibenzothiophene species, respectively. And the regeneration behaviour suggests that the spent membranes can recover about 88% and 96% of the desulfurization capacity by solvent washing and thermal treating regeneration, respectively. The related discussions provide some general suggestions in promoting the novel application of MMMs on the separation of organic-organic mixtures, and a potential alternative for the production of sulfur-free hydrogen source for fuel cell applications.

13/01824 Reverse gas-lift technology for CO₂ storage into deep saline aquifers

Shafaei, M. J. *et al. Energy*, 2012, 45, (1), 840–849.

The authors have developed an injection well design to reduce the cost of CO₂ sequestration. This paper proposes a reverse gas-lift technology for simultaneous injection of CO₂ and water into aquifers. Saline water, which is produced at a location distant from the storage site, is pumped

into a well through tubing; CO₂ is injected using the annular space between the tubing and the casing. One way gas-lift valves installed along the tubing allow the flow of CO₂ from the annulus into the tubing. This design makes the injection achievable at lower wellhead pressures, thereby, decreasing the compression costs. Simulation results demonstrate that the compression cost is lower than when a conventional injection scheme is used. The results also reveal that the proposed design can decrease the energy consumption for CO₂ sequestration. These results have implications for the large-scale implementation of CO₂ sequestration.

13/01825 Stochastic carbon sinks for combating carbon dioxide emissions in the EU

Gren, I.-M. *et al. Energy Economics*, 2012, 34, (5), 1523–1531.

This paper carries out numerical calculations on the potential of carbon sinks in the European Union's (EU) Emissions Trading Scheme (ETS) and national commitments under conditions of stochastic carbon dioxide emissions from fossil fuels and carbon sequestration by forests. Chance constraint programming is used to analyse the role of stochastic carbon sinks for national and EU-wide compliance costs. The analytical results show that the inclusion of the carbon sink option can reduce costs for low enough marginal cost and risk discount, but also that costless carbon sinks as by-products from forestry are not part of a cost-effective solution under a high reliability concern. Cost-savings are reduced due to risk discounting under a reliability concern, in particular when assigning Chebyshev's inequality as compared with a normal probability distribution. It is also shown that the supply of forest sinks on the market depends on the differences in marginal abatement cost between the trading and the non-trading sectors, and in risk discounting between achievements of the ETS cap and the national commitment. Relatively low marginal abatement cost in the non-trading sector and high risk discounting of national commitment achievements increase the supply of sinks in the market and, hence, reduces the equilibrium price. The empirical application illustrates the importance of risk discounting for the magnitude of cost savings obtained from introducing forest carbon sinks in the EU ETS and national commitments.

13/01826 The effect of assessment scale and metric selection on the greenhouse gas benefits of woody biomass

Galik, C. S. and Abt, R. C. *Biomass and Bioenergy*, 2012, 44, 1–7.

Recent attention has focused on the net greenhouse gas (GHG) implications of using woody biomass to produce energy. In particular, a great deal of controversy has erupted over the appropriate manner and scale at which to evaluate these GHG effects. Here, the authors conduct a comparative assessment of six different assessment scales and four different metric calculation techniques against the backdrop of a common biomass demand scenario. They evaluate the net GHG balance of woody biomass co-firing in existing coal-fired facilities in the state of Virginia, finding that assessment scale and metric calculation technique do in fact strongly influence the net GHG balance yielded by this common scenario. Those assessment scales that do not include possible market effects attributable to increased biomass demand, including changes in forest area, forest management intensity, and traditional industry production, generally produce less-favourable GHG balances than those that do. Given the potential difficulty small operators may have generating or accessing information on the extent of these market effects, however, it is likely that stakeholders and policy makers will need to balance accuracy and comprehensiveness with reporting and administrative simplicity.

13/01827 The effect of mechanical rock properties on CO₂ storage capacity

Vulin, D. *et al. Energy*, 2012, 45, (1), 512–518.

One of the most important issues when estimating CO₂ storage capacity, especially in the case of the storage into deep saline aquifers, is the mechanical integrity of rock, i.e. estimate of cap rock fracture pressure. In the case of storage into mature oil and gas reservoirs, reservoir pressure should not present an issue since it was significantly decreased due to hydrocarbon production, so it is reasonable to assume that the rock integrity would not be disturbed by injecting CO₂ to the initial reservoir pressure. Because estimates of fracture pressure are necessary, but not convenient for regional aquifers, the analysis of pore volume changes due to pressure build-up for the chosen CO₂ site in Croatia has been made. Pressure build-up depends on reservoir fluid (brine) compressibility, CO₂ compressibility at given reservoir conditions before CO₂ injection and on rock compressibility, i.e. pore compressibility. Implementing the simple method for analysis of pressure build-up considering elastic properties of fluids and rock, larger CO₂ storage capacity estimate was achieved than by using storage efficiency coefficient, as defined by US DOE and which was used for estimating storage capacities in regional deep saline aquifers in Croatia as the part of European Union GeoCapacity project.

13/01828 Tracing industrial sulfur contributions to atmospheric sulfate deposition in the Athabasca oil sands region, Alberta, Canada

Proemse, B. C. *et al. Applied Geochemistry*, 2012, 27, (12), 2425–2434. Anthropogenic S emissions in the Athabasca oil sands region (AOSR) in Alberta, Canada, affect SO_4 deposition in close vicinity of industrial emitters. Between May 2008 and May 2009, SO_4 -S deposition was monitored using open field bulk collectors at 15 sites and throughfall collectors at 14 sites at distances between 3 and 113 km from one of the major emission stacks in the AOSR. At forested plots >90 km from the operations, SO_4 deposition was $\sim 1.4 \text{ kg SO}_4\text{-S ha}^{-1}\text{yr}^{-1}$ for bulk deposition and $\sim 3.3 \text{ kg SO}_4\text{-S ha}^{-1}\text{yr}^{-1}$ for throughfall deposition. Throughfall SO_4 deposition rates in the AOSR exceeded bulk deposition rates at all sites by a factor of 2–3, indicating significant inputs of dry deposition especially under forest canopies. Both bulk and throughfall SO_4 deposition rates were elevated within 29 km distance of the industrial operations with deposition rates as high as $11.7 \text{ kg SO}_4\text{-S ha}^{-1}\text{yr}^{-1}$ for bulk deposition and $39.2 \text{ kg SO}_4\text{-S ha}^{-1}\text{yr}^{-1}$ for throughfall at industrial sites. Sulfur isotope ratio measurements of atmospheric SO_4 deposited in the AOSR revealed that at a few selected locations ^{34}S -depleted SO_4 , likely derived from H_2S emissions from tailing ponds contributes to local atmospheric SO_4 deposition. In general, however, $\delta^{34}\text{S}$ values of SO_4 deposition at distant forested plots (>74 km) with low deposition rates were not isotopically different from $\delta^{34}\text{S}$ values at sites with high deposition rates in the AOSR and are, therefore, not suitable to determine industrial S contributions. However, O isotope ratios of atmospheric SO_4 in bulk and throughfall deposition in the AOSR showed a distinct trend of decreasing $\delta^{18}\text{O}$ - SO_4 values with increasing SO_4 deposition rates allowing quantification of industrial contributions to atmospheric SO_4 deposition. Two-end-member mixing calculations revealed that open field bulk SO_4 deposition especially at industrial sites in close proximity (<29 km) to the operations is significantly (17–59%) affected by industrial S emissions and that throughfall generally contained 49–100% SO_4 of industrial origin. Hence, it is suggested that $\delta^{18}\text{O}$ values of SO_4 may constitute a suitable tracer for quantifying industrial contributions to atmospheric SO_4 deposition in the AOSR.

13/01829 Trends in NO_x and NO_2 emissions from road traffic in Great Britain

Beevers, S. D. *et al. Atmospheric Environment*, 2012, 54, 107–116. This paper compares detailed road traffic NO_x emissions with the equivalent trends in ambient roadside NO_x measurements. This was undertaken separately in Great Britain and London, for all of the major roads, and by road type and location. The emissions trends were created using different emissions factors, those used in UK emissions' inventories (base case), the Swiss-German handbook (HBEFA), and those created from recent remote sensing measurements in the UK (RSD). An alternative assumption for use of selective catalytic reduction (SCR) in the articulated heavy goods vehicle fleet was also tested. For all scenarios traffic flows, speeds and vehicle age were kept constant. Comparison between the emissions scenarios in Great Britain showed that by 2009, NO_x emissions estimates from road traffic could be as much as 25% greater than current UK estimates and 31% greater in London. The RSD emissions inventory gave the smallest downward trend in NO_x emissions, from 2004 to 2009, of between 3 and 4%/year and this compared with a reduction of $\sim 6\%$ /year from the base case and HBEFA scenarios. All scenarios compared poorly with roadside NO_x measurement trends from UK sites, which typically reduce by between 1% and 2%/year. The authors have shown that the differences in NO_x emissions trends were driven, partially at least, by the relative contribution from light duty diesel vehicles. An analysis from 2700 NO_x measurement sites throughout Europe has shown that this problem is unlikely to be limited to the UK, and identifies a difficulty in meeting European Union limit values for NO_2 , obligations under the 2001 National Emission Ceilings Directive and the 1999 Gothenburg Protocol and for forecasting future changes in $\text{PM}_{2.5}$.

13/01830 We keep on truckin': trends in freight energy use and carbon emissions in 11 IEA countries

Eom, J. *et al. Energy Policy*, 2012, 45, 327–341. Based on detailed national and international data on freight transportation, the authors analyse trends in freight CO_2 emissions in 11 International Energy Agency (IEA) countries from the earliest year of data availability to 2007–2010. The cross-country comparison of the freight transportation sector indicates that per capita CO_2 emissions span a wide range and are mostly determined by local needs without full knowledge or coordination with policies and practices in other countries. Over the last several decades, while many developed countries have experienced decreased coupling between total freight activity (measured in tonne-km) and income, no major indication of decreased coupling between trucking and income was found. Rather, the coupling has been strengthened in many countries due to a continued increase in the share of trucking in total freight activity. The energy intensity of trucking has exhibited very large variation among

the countries, and its recent international trends are mixed, providing greater challenges to reduce freight CO_2 emissions. Modal shift toward rail away from truck presents a sizeable opportunity to reduce freight CO_2 emissions, although the potential gain varies widely among the countries.

Hydrocarbon emissions

13/01831 Atmospheric polycyclic aromatic hydrocarbon profiles and sources in pine needles and particulate matter in Dayton, Ohio, USA

Tomashuk, T. A. *et al. Atmospheric Environment*, 2012, 51, 196–202. Polycyclic aromatic hydrocarbons (PAHs) were measured in pine needles (passive sampling) and on high-volume particulate matter (PM) filters (active sampling) over a period of 8–10 months at two separate sites in the Dayton, Ohio, USA metropolitan area: Moraine and Yellow Springs. Total PAH concentrations for PM ranged from 77.4 to $837 \mu\text{g g}^{-1}$ (dry weight) at both sites with high molecular weight PAHs being the predominant form that tended to be higher in concentration during the colder months. Total PAH concentrations for pine needles varied by tree species and location. With an average concentration of 4187 ng g^{-1} , Austrian pine (*Pinus nigra*) needles in Moraine ranged from 2543 to 6111 ng g^{-1} (dry weight) with the lowest and highest concentrations occurring in October and August, respectively. The amount of phenanthrene was extremely high for August, 4200 ± 112 , which could have resulted from the close proximity of the tree to the parking lot at a firehouse. White pine (*Pinus strobus*) needles in Yellow Springs had an average concentration of 384 ng g^{-1} and ranged from 127 to 589 ng g^{-1} (dry weight) with September and November, respectively, having the lowest and highest PAH concentrations. The two- and three-ring PAHs were the predominant form in *P. nigra*, while the four-ring PAHs predominated in *P. strobus*. Total PAH concentrations in *P. nigra* were an order of magnitude greater than for *P. strobus*. A bivariate plot of $\text{BaA}/(\text{BaA} + \text{Chry})$ versus $\text{Flt}(\text{Flt} + \text{Pyr})$ allowed the PM and pine needle data to be included in the same source analysis and indicated sources of PM at both sites were biomass and/or coal combustion. This plot also suggested PAHs in Yellow Springs *P. strobus* originated from petroleum combustion sources, whereas PAHs in Moraine *P. nigra* originated from petroleum combustion with some sources more aged or remote.

13/01832 Evaluation of ginkgo as a biomonitor of airborne polycyclic aromatic hydrocarbons

Murakami, M. *et al. Atmospheric Environment*, 2012, 54, 9–17. The utility of ginkgo leaves as biomonitors of airborne polycyclic aromatic hydrocarbons (PAHs) was evaluated. The authors investigated PAH concentrations among tree species, the effect of variations in leaf position in a tree, tissue distributions, correlations between ginkgo leaves and air, and seasonal variations. Among the five species examined (*Ginkgo biloba* L., *Zelkova serrata* Makino, *Liriodendron tulipifera* L., *Prunus yedoensis* Matsum., and *Magnolia kobus* DC.), ginkgo accumulated the greatest amount of PAHs from roadside air. Most PAHs ($\sim 80\%$) were accumulated in the wax fraction, and most of the remainder (17%) penetrated the inner tissues of the leaves. PAH concentrations in ginkgo leaves decreased with increasing height and distance from the road, reflecting the derivation of PAHs from vehicle emissions. Seasonal time-series sampling showed that PAH concentrations in ginkgo leaves increased with time, attributable to the effects of temperature and accumulation through long-term exposure. Concentrations in ginkgo leaves collected from various roads showed a strong and significant correlation with those in air collected by a high-volume air sampler ($r^2 = 0.68$, $P < 0.01$). Ginkgo leaf data clearly showed a dramatic decrease in the ratio of low-molecular-weight (LMW) PAHs to high-molecular-weight PAHs from 2001 or 2002 to 2006, indicating that on-road diesel emission regulations effectively reduced LMW PAH concentrations in air.

13/01833 PAH volatilization following application of coal-tar-based pavement sealant

Van Metre, P. C. *et al. Atmospheric Environment*, 2012, 51, 108–115. Coal-tar-based pavement sealants, a major source of polycyclic aromatic hydrocarbons (PAHs) to urban water bodies, have recently been identified as a source of volatile PAHs to the atmosphere. The authors tracked the volatilization of PAHs for 1 year after application of a coal-tar-based pavement sealant by measuring gas-phase PAH concentrations above the pavement surface and solid-phase PAH concentrations in sealant scraped from the surface. Gas-phase concentrations at two heights (0.03 and 1.28 m) and wind speed were used to estimate volatilization flux. The sum of the concentrations of eight frequently detected PAHs (ΣPAH_8) in the 0.03-m sample 1.6 h after application ($297,000 \text{ ng m}^{-3}$) was about 5000 times greater than

that previously reported for the same height above unsealed parking lots (66 ng m^{-3}). Flux at 1.6 h after application was estimated at $45,000 \mu\text{g m}^{-2} \text{ h}^{-1}$ and decreased rapidly during the 45 days after application to $160 \mu\text{g m}^{-2} \text{ h}^{-1}$. Loss of PAHs from the adhered sealant also was rapid, with about a 50% decrease in solid-phase ΣPAH_8 concentration over the 45 days after application. There was general agreement, given the uncertainties, in the estimated mass of ΣPAH_8 lost to the atmosphere on the basis of air sampling ($2\text{--}3 \text{ g m}^{-2}$) and adhered sealant sampling (6 g m^{-2}) during the first 16 days after application, translating to a loss to the atmosphere of one-quarter to one-half of the PAHs in the sealcoat product. Combining the estimated mass of ΣPAH_8 released to the atmosphere with a national-use estimate of coal-tar-based sealant suggests that PAH emissions from new coal-tar-based sealcoat applications each year ($\sim 1000 \text{ Mg}$) are larger than annual vehicle emissions of PAHs for the United States.

13/01834 Small-scale co-utilisation of coal and biomass

Kubacki, M. L. *et al. Fuel*, 2012, 101, 84–89.

Co-utilization of coal and biomass for energy production results in pollutant reduction. Most notable is the impact on NO_x , SO_x , volatile organic compounds (VOC) and polyaromatic hydrocarbons (PAH). The aim of this study is to improve the understanding of the synergy in toxic organic emission reduction from co-firing or co-gasifying coal and biomass. Co-combustion was studied by TGA and by burning briquettes supported on a needle in a methane air flame. A range of coals of varying rank, different biomass, as well as model compounds were used. Results show that non-additive combustion behaviour is not easily explained by studying devolatilization because of the difficulty in replicating the conditions of temperature profile and residence time experienced by the volatiles. Thus, conflicting behaviour is exhibited depending on pyrolysis technique. However, the atmosphere during experiments appears to be more important. Non-additive combustion for both powdered and pelletized fuels was seen by TGA and studies in a methane-air burner. The coal ignites and burns at a lower temperature because of the interaction with the biomass volatile combustion region. Thus it is proposed that the reduction in emissions from co-combustion arises from enhanced reaction of the coal volatiles by mixing with biomass volatiles in a hot oxidizing atmosphere.

13/01835 The occurrence and distribution of phenylphenanthrenes, phenylanthracenes and binaphthyls in Palaeozoic to Cenozoic shales from China

Li, M. *et al. Applied Geochemistry*, 2012, 27, (12), 2560–2569.

The distributions of phenylphenanthrenes, phenylanthracenes and binaphthyls in sediment extracts have been investigated in a set of lacustrine shales from the Eocene Shahejie Formation (well SG 1) in the western depression of Liaohai Basin, east China. All isomers of these phenyl substituted polycyclic aromatic hydrocarbons (PAHs) have been identified in the m/z 254 mass chromatograms by comparison of the mass spectra and standard retention indices with those published elsewhere. The 2,2'-binaphthyl/1,2'-binaphthyl ratio values show a linear increase with increasing maturity, and have a good correlation with T_{max} ($^{\circ}\text{C}$). Therefore, they can be used as an effective maturity indicator for source rocks in this study. In the main phase of the oil generation window, the 3-phenylphenanthrene and 2-phenylphenanthrene prevail over other isomers, and some thermodynamically unstable isomers including all phenylanthracenes, 4-phenylphenanthrene and 1,1'-binaphthyl are present at very low concentrations or below the detection limit in the m/z 254 mass chromatograms. The absolute concentrations of individual phenylphenanthrene and binaphthyl isomers were obtained by comparison of the peak areas with that of internal standard phenanthrene-d10. All isomers are present at low concentrations at low maturity stages and then show an abrupt increase at a depth of $\approx 3100 \text{ m}$, corresponding to the onset of the intensive C_{15+} hydrocarbon generation. The Phenylphenanthrene Ratio $(2 + 3\text{-PhP}) / [(2 + 3\text{-PhP}) + (4 + 1 + 9\text{-PhP})]$ shows a reverse change with increasing maturity at the low maturity stage. It displays a drastic increase at a depth of $\approx 3100 \text{ m}$ and then remains at a nearly constant value. This study can expand the understanding of the formation and distribution of phenyl substituted PAHs in sedimentary organic matter deposited in various environments.

Life cycle analysis

13/01836 Addressing land use change and uncertainty in the life-cycle assessment of wheat-based bioethanol

Malça, J. and Freire, F. *Energy*, 2012, 45, (1), 519–527.

Despite the significant growth in the number of published life-cycle assessments of biofuels, important aspects have not captured sufficient attention, namely soil carbon emissions from land-use change (LUC) and uncertainty analysis. The main goal of this article is to evaluate the

implications of different LUC scenarios and uncertainty in the life-cycle energy renewability efficiency and greenhouse gas (GHG) intensity of wheat-based bioethanol replacing gasoline. A comprehensive assessment of different LUC scenarios (grassland or cropland converted to wheat cultivation) and agricultural practices is conducted, which results in different carbon stock change values. The types of uncertainty addressed include parameter uncertainty (propagated into life-cycle results using Monte Carlo simulation) and uncertainty concerning how bioethanol co-product credits are accounted for. Results show that GHG emissions have considerably higher uncertainty than energy efficiency values, mainly due to soil carbon emissions from direct LUC and N_2O release from cultivated soil. Moreover, LUC dominates the GHG intensity of bioethanol. Very different GHG emissions are calculated depending on the LUC scenario considered. Conversion of full- or low-tillage croplands to wheat cultivation results in bioethanol GHG emissions lower than gasoline emissions, whereas conversion of grassland does not contribute to bioethanol GHG savings over gasoline in the short-term to the mid-term.

13/01837 An energy and carbon life cycle assessment of tidal power case study: the proposed Cardiff–Weston Severn barrage scheme

Kelly, K. A. *et al. Energy*, 2012, 44, (1), 692–701.

Under the Kyoto Protocol many countries have targets to reduce carbon emissions and increase renewable energy production. In order to do this effectively the impact and efficacy of differing schemes must be determined. One option for producing electricity is through the use of a tidal barrage. The largest potential barrage scheme considered in the UK is the Cardiff–Weston barrage scheme in the Severn estuary. The scheme would be a single, renewable installation and is predicted to constitute 4% of the UK's electricity supply. Therefore, a carbon and energy assessment was completed on the Cardiff–Weston Severn barrage scheme. The assessment shows that the energy and carbon intensity of the Severn barrage is small in comparison to the National Grid mix and that, given reasonable assumptions, the Severn barrage can contribute to meeting the UK carbon reduction target. Importantly, the operation stage was identified as both the most energy and carbon intense by a large margin. This is a notable finding as preceding studies have tended to dismiss the consequences of the barrage operation as minimal or nil. While these findings are for the Cardiff–Weston barrage, the implications will be similar for tidal barrages in other sites in the UK and globally.

13/01838 Analysing the life cycle greenhouse gas emission and energy consumption of a multi-storied commercial building in Singapore from an extended system boundary perspective

Kua, H. W. and Wong, C. L. *Energy and Buildings*, 2012, 51, 6–14.

Building life cycles contribute substantially to the emission of greenhouse gases and energy consumption; this is especially true for the operation or use stage of the building. This work on a commercial building in Singapore extends the traditional system boundary drawn for a whole-building life cycle assessment to include the management of wastes produced during building operations. It was found that waste management produces much more emissions than the operation stage. This reinforced the notion that waste recycling should be further promoted in buildings, possibly through building level technological innovations and design modifications. An integrated policy framework was proposed to explore ways by which building level strategies can work with other strategies to holistically address the issues of waste reduction, sorting, collection and recycling.

13/01839 Evaluation of the life cycle of bioethanol produced from rice straws

Roy, P. *et al. Bioresource Technology*, 2012, 110, 239–244.

This study evaluated the life cycle of bioethanol produced by enzymatic hydrolysis of rice straw. Net energy consumption, CO_2 emission and production costs were estimated to determine whether environmentally preferable and economically viable bioethanol can be produced from rice straws. Two varieties of rice straw (*Koshihikari* and *Leafstar*), three energy scenarios (F-E-RH: fuel–electricity–residues used for heat; F-E-RE: fuel–electricity–residues used to generate electricity; F-RE: fuel–residues used to generate electricity) and three types of primary energy (heavy oil; LNG: liquefied natural gas; agri-residues) were considered. The net energy consumption, CO_2 emission and production costs were estimated to be $10.0\text{--}17.6 \text{ MJ/L}$, -0.5 to 1.6 kg/L and $\text{¥}84.9\text{--}144.3/\text{L}$ ($\text{US\$}1 \approx \text{¥}100$), respectively, depending on the feedstock and scenarios of this study. A shift in energy scenarios or in the type of primary energy (heavy oil to LNG or agri-residues) not only reduces emissions and production costs of bioethanol from rice straw, but may also reduce the fluctuation in production cost over time and risk on investment, which would encourage more investment in this sector.

13/01840 Life cycle assessment of a fluidized bed system for steam production

Çetinkaya, E. *et al. Energy Conversion and Management*, 2012, 63, 225–232.

A life cycle assessment (LCA) is reported of a fluidized bed steam plant utilized in a textile factory in Torbalı, Izmir, Turkey. Soma lignite is consumed as primary fuel, which has a comparatively high sulfur content. The LCA steps are coal mining, coal transportation, coal cleaning, plant operation, limestone use for desulfurization, and landfill of ash and calcium sulfate. Production and decommissioning for mining and landfilling equipment are considered in terms of carbon dioxide equivalent as well as energy consumption. The assessment is conducted for a lifetime of 30 years of operation. It is found that the main source of carbon dioxide emission is the operation of the steam plant and that the main materials that have a major impact on energy use are steel and concrete.

13/01841 Life cycle assessment of gasoline and diesel produced via fast pyrolysis and hydroprocessing

Hsu, D. D. *Biomass and Bioenergy*, 2012, 45, 41–47.

Pyrolysis of biomass followed by hydroprocessing may provide infrastructure-compatible transportation fuels. In this work, a life cycle assessment (LCA) of the production of gasoline and diesel from forest residues via fast pyrolysis and hydroprocessing, from production of the feedstock to end use of the fuel in a vehicle, is performed. The fast pyrolysis and subsequent hydrotreating and hydrocracking processes are based on a Pacific Northwest National Laboratory design report. Stages other than biofuels conversion, including forest residue production and harvesting, preprocessing, feedstock transportation, fuel distribution, and vehicle operation, are based on previous work. Probability distribution functions are assumed for parameters involved in the pyrolysis process for Monte Carlo uncertainty analysis. This LCA for the production of gasoline and diesel via pyrolysis and upgrading assumes grid electricity is used and supplemental natural gas is supplied to the hydrogen plant. Gasoline and diesel produced via pyrolysis are estimated to have greenhouse gas (GHG) emissions of CO₂ equivalent of 117 g km⁻¹ and 98 g km⁻¹, respectively, and net energy value (NEV) of 1.09 MJ km⁻¹ and 0.92 MJ km⁻¹, respectively. All values from the uncertainty analysis have lower GHG emissions and higher NEV than conventional gasoline in 2005. Grid electricity and natural gas used account for 81% of the net GHG emissions in the base case. An evaluation of a case with biomass-derived electricity shows significant improvement in GHG emissions.

13/01842 Life cycle assessment of sugarcane ethanol and palm oil biodiesel joint production

Souza, S. P. *et al. Biomass and Bioenergy*, 2012, 44, 70–79.

Sugarcane (*Saccharum* spp.) and palm tree (*Elaeis guineensis*) are crops with high biofuel yields, 7.6 m³ ha⁻¹ y⁻¹ of ethanol and 4 Mg ha⁻¹ y⁻¹ of oil, respectively. The joint production of these crops enhances the sustainability of ethanol. The objective of this work was comparing a traditional sugarcane ethanol production system (TSES) with a joint production system (JSEB), in which ethanol and biodiesel are produced at the same biorefinery but only ethanol is traded. The comparison is based on ISO 14040:2006 and ISO 14044:2006, and appropriate indicators. Production systems in Cerrado (typical savannah), Cerradão (woody savannah) and pastureland ecosystems were considered. Energy and carbon balances, and land use change impacts were evaluated. The joint system includes 100% substitution of biodiesel for diesel, which is all consumed in different cropping stages. Data were collected by direct field observation methods, and questionnaires applied to Brazilian facilities. Three sugarcane mills situated in São Paulo state and one palm oil refinery located in Pará state were surveyed. The information was supplemented by secondary sources. Results demonstrated that fossil fuel use and greenhouse gas emissions decreased, whereas energy efficiency increased when JSEB was compared to TSES. In comparison with TSES, the energy balance of JSEB was 1.7 greater. In addition, JSEB released 23% fewer GHG emissions than TSES. The ecosystem carbon payback time for Cerrado, Cerradão, and degraded grassland of JSEB was respectively 4, 7.7 and –7.6 years. These are typical land use types of the Brazilian Cerrado region for which JSEB was conceived.

13/01843 Life cycle assessment of two alternative bioenergy systems involving *Salix* spp. biomass: bioethanol production and power generation

González-García, S. *et al. Applied Energy*, 2012, 95, 111–122.

Two energy production systems using short rotation coppice (SRC) willow chips were evaluated: bioethanol production via enzyme-catalysed hydrolysis and electricity production following a biomass integrated gasification combined cycle scheme. The most relevant input and output flows of each renewable energy system were identified and quantified throughout the life cycle from the SRC willow plantation to the bioenergy plant gate. Both bioenergy systems were found to be feasible from an energy perspective. Moreover, they entailed environ-

mental benefits when compared to conventional energy practices. However, improvements relating to not only willow biomass production but also bioenergy conversion-related activities should be considered. In this respect, the process steps that provided the highest environmental impacts have been highlighted. Furthermore, well-to-wheels environmental characterization results were estimated and compared for the bioethanol and bioelectricity scenarios. In this sense, the identification of the most appropriate processing route for willow chips was found to be highly dependent on the impact category under assessment. In particular, global warming and energy parameters led to opposite conclusions. While the bioethanol scenario arose as the potentially best choice from an energy perspective, the bioelectricity scenario seems to be a more suitable alternative when global warming is the decisive factor.

13/01844 Life cycle greenhouse gas emissions estimation for small hydropower schemes in India

Varun, *Energy*, 2012, 44, (1), 498–508.

This paper presents for the first time correlations for greenhouse gas (GHG) emissions from small hydropower schemes in India. In this paper an attempt has been made to develop life cycle GHG emissions correlations for three different types of small hydropower schemes (run-of river, canal based and dam-toe) in India. It has been found out that GHG emissions depend on the head and capacity of the small hydropower project. The results obtained from correlations show good agreement with the estimated results using EIO-LCA (economic input-output-life cycle assessment) technique. These correlations may be useful for the development of new small hydropower (SHP) schemes, as they can be used to predict life cycle GHG emissions based on capacity, head and type of SHP schemes.

13/01845 Scenarios for the environmental impact of fossil fuel power: co-benefits and trade-offs of carbon capture and storage

Singh, B. *et al. Energy*, 2012, 45, (1), 762–770.

This study uses a hybrid life cycle assessment approach to evaluate the environmental impacts of large-scale deployment of carbon dioxide capture and storage (CCS) in coal and natural gas based electricity generation, based on IEA scenarios. For the baseline scenario, all impact categories would increase two- to three-fold in 2050 from 2005 levels. Greenhouse gas (GHG) emissions are found to decrease by ~40% in ACTmap scenario and by ~75% in more CCS-intensive BLUEmap scenario. These climate mitigation scenarios also show significantly reduced impacts of acidification, particulate matter formation and human toxicity, suggesting the existence of co-benefits. For eutrophication, all scenarios indicate substantial increases, but the increases are largest in the Baseline scenario. For photochemical oxidant formation, only the mitigation scenarios manage to stabilize this impact from fossil fuel based power production. This study does not assess the impact of alternative power generation or energy efficiency technology that replaces part of the fossil fuel power in the mitigation scenarios.

13/01846 Streamlined life cycle assessment of transparent silica aerogel made by supercritical drying

Dowson, M. *et al. Applied Energy*, 2012, 97, 396–404.

When developing sustainable building fabric technologies, it is essential that the energy use and CO₂ burden arising from manufacture does not outweigh the respective in-use savings. This study investigates this paradigm by carrying out a streamlined life cycle assessment (LCA) of silica aerogel. This unique, nanoporous translucent insulation material has the lowest thermal conductivity of any solid, retaining up to four times as much heat as conventional insulation, whilst being highly transparent to light and solar radiation. Monolithic silica aerogel has been cited as the 'holy grail' of future glazing technology. Alternatively, translucent granular aerogel is now being produced on a commercial scale. In each case, many solvents are used in production, often accompanied by intensive drying processes, which may consume large amounts of energy and CO₂. To date, there has been no peer-reviewed LCA of this material conducted to the ISO 14000 standard. Primary data for this 'cradle-to-factory gate' LCA is collected for silica aerogel made by low and high temperature supercritical drying. In both cases, the mass of raw materials and electricity usage for each process is monitored to determine the total energy use and CO₂ burden. Findings are compared against the predicted operational savings arising from retrofitting translucent silica aerogel to a single glazed window to upgrade its thermal performance. Results should be treated as a conservative estimate as the aerogel is produced in a laboratory, which has not been developed for mass manufacture or refined to reduce its environmental impact. Furthermore, the samples are small and assumptions to upscale the manufacturing volume occur without major changes to production steps or equipment used. Despite this, parity between the CO₂ burden and CO₂ savings is achieved in less than 2 years, indicating that silica aerogel can provide a measurable environmental benefit.

16 ENERGY

Supplies, policy, economics, forecasts

13/01847 A feasibility study on solar-wall systems for domestic heating – an affordable solution for fuel poverty

Wang, F. *et al. Solar Energy*, 2012, 86, (9), 2405–2415.

A solar wall heating (SWH) system was developed to provide low-cost space heating in traditional solid stone-walled tenement buildings in Scotland. The SWH system uses the internal solid walls to store the solar heat collected during the day and heat the bedrooms during the night. A physical laboratory model with attached solar hot water system and a computational model of it were developed to investigate the dynamic performance of the system in use and test the cost benefits of iterations of its modes of use. The temperatures throughout the wall structure were measured under the variant solar input of a 24-h cycle. An unsteady state computational fluid dynamics model was developed and validated using the measured data and setup to test a number of key variables of the solar wall heating system in use. These included optimization control strategies and maximization strategies for the collection and storage of solar heat under various conditions. This paper presents the modelled results of the solar thermal storage and optimization system and strategies for internal solid stone walls in a typical Scottish tenement flat in the Scottish climate. In addition the study analysed the solar availability, heating demand and domestic water supply of two typical dwellings based on two reliable methods: (a) a purpose-built dynamic thermal model and (b) data collected in previous studies. The study demonstrated that the solar collection of current solar hot water systems can be improved on so that, even in Scotland, more solar power can be harvested to contribute not only to domestic hot water, but also domestic space heating, particularly in buildings occupied over 24 h with heavy thermal mass. The cost analysis of the system in use suggested a 16-year payback period for such a system for a tenement flat.

13/01848 A new paradigm for the design and management of building systems

Lawrence, T. M. *et al. Energy and Buildings*, 2012, 51, 56–63.

Leveraging the emerging technologies of energy informatics and cross-reality, a new concept is proposed for how buildings and their systems are designed and operated. The basic premise of energy informatics contends that information has the power to reduce energy consumption, which, in a simple fashion, is asserted as 'energy + information = less energy'. The concept of informatics can be applied to energy issues in the built environment from scales ranging from individual pieces of equipment (such as with fault detection and diagnostics) up to regional or country level (such as with a smart electrical grid). Facilities management and modelling (FMM) is introduced as a new form of information systems to apply the principles of energy informatics to increasing energy efficiency in building operations. There are three core principles that guide the design of FMM: measurement, modelling, and management. The characteristics and use of FMM are discussed. Also introduced are potential applications for how cross-reality concepts can be applied in the training of students and professionals in the operation of complex building systems.

13/01849 A simulation model for reliability-based appraisal of an energy policy: the case of Lebanon

Hamdan, H. A. *et al. Energy Policy*, 2012, 45, 293–303.

The Lebanese Electric Power System (LEPS) has been suffering from technical and financial deficiencies for decades and mirrors the problems encountered in many developing countries suffering from inadequate or no power systems planning resulting in incomplete and ill-operating infrastructure, and suffering from effects of political instability, huge debts, unavailability of financing desired projects and inefficiency in operation. The upgrade and development of the system necessitate the adoption of a comprehensive energy policy that introduces solutions to a diversity of problems addressing the technical, financial, administrative and governance aspects of the system. In this paper, an energy policy for Lebanon is proposed and evaluated based on integration between energy modelling and financial modelling. The paper utilizes the load modification technique as a probabilistic tool to assess the impact of policy implementation on energy production, overall cost, technical/commercial losses and reliability. Scenarios reflecting implementation of policy projects are assessed and their impacts are compared with business-as-usual scenarios which assume no new investment is to take place in the sector. Conclusions are drawn on the usefulness of the proposed evaluation methodology and the effectiveness of the adopted energy policy for Lebanon and other developing countries suffering from similar power system problems.

13/01850 An energy source policy assessment using analytical hierarchy process

Erol, Ö. and Kilkis, B. *Energy Conversion and Management*, 2012, 63, 245–252.

Energy resource planning for a district in the built environment is a challenging issue for the authorities. They have to take many criteria into account in order to derive sustainable, robust, and long-term energy policies. Among these criteria authorities have to look at the alternatives from different point of views, such as the environmentalists, industry, local community, and local authorities of that district. In this study, an analytical hierarchy process (AHP) method was developed in order to facilitate energy resource planning activities. This method was applied to the district of Aydin in Turkey. Hypothetical results showed that solar energy investments has the highest priority and can be realized by local residents and government, while industry and government can make investments for geothermal power plants and de-centralized lignite power plants using clean technology.

13/01851 An improved two-step floating catchment area method for supporting district building energy planning: a case study of Yongding County city, China

Yu, D. *et al. Applied Energy*, 2012, 95, 156–163.

Traditional energy planning methods emphasize the total energy supply equalling to the total demand and neglect details of the distribution in energy demand and supply within a region or city. An improved two-step floating catchment area (2SFCA) method is developed to reflect internal heterogeneity in energy demand and/or supply and address interactions between them based on respective catchment sizes of different categories of energy sources in a GIS digital environment. The first part of the method delineates how to allocate a variety of energy sources within their service boundaries. The second part evaluates how much to be obtained by a consumer from the available energy sources. Subsequently, it is applied to a case study of Yongding County city, China for supporting district building energy planning. The results show that the improved 2SFCA method can address interactions between energy demand and supply across tax lots and can help planners make precise decisions on selecting what energy sources to meet specific categories of spatial energy demand.

13/01852 Analysis of innovative micro-CHP systems to meet household energy demands

Barbieri, E. S. *et al. Applied Energy*, 2012, 97, 723–733.

This paper presents an analysis aimed to evaluate the feasibility of micro-combined heat and power (CHP) systems to meet the household energy demands of single family users. The considered CHP systems, with an electric power output of a few kilowatts, are based on technologies (internal combustion engines, micro-gas turbines, micro-Rankine cycles, Stirling engines and thermophotovoltaic generators) which are already available on the market or will be available in the near future. Each CHP system is composed of (i) a prime mover, (ii) a thermal energy storage unit and (iii) an auxiliary boiler used to cover peak thermal demands. The analyses performed in this paper aim to evaluate (i) the energy performance of the CHP systems to meet the energy demand of two single-family dwellings, with different floor areas and shape factors, and (ii) the maximum cost allowed for each CHP system. The results presented in this paper allow the most suitable technology, prime mover and thermal energy storage unit size to be identified. From an energy point of view, the considered CHP systems usually satisfy most of the thermal and electric energy demand, with a primary energy saving index that is always higher than 20%. Moreover, the correct sizing of the thermal energy storage unit capacity proves crucial. As regards economic feasibility, it is shown that a reasonable target for the marginal cost of a CHP system for household heating is approximately €3000/kW_e, even though the absence of incentives does not make any of the technologies very attractive at present. It is also shown that the highest profitability can be obtained by using the prime mover (i) with the lowest electric power output closest to that of the peak electric demand and (ii) with an electric-to-thermal ratio which fits the electric-to-thermal ratio of the users.

13/01853 Assessing the benefits of regulating power market integration in Northern Europe

Jaehnert, S. and Doorman, G. L. *International Journal of Electrical Power & Energy Systems*, 2012, 43, (1), 70–79.

The expected increase of intermittent electricity production from renewable sources in northern Europe poses rising challenges to the balancing of the power system. The Nordic hydro-based power system, particularly the Norwegian, is in a favourable position to provide the necessary balancing services. In order to provide these services to continental Europe an integration of markets for balancing services (regulating power market) might be advantageous. Contemporaneously, the European Union enforces the liberalization and integration of national European power markets, including the regulating power markets. To investigate the possible outcome of such an

integrated market, a regulating power market model is developed, which is based on a common day-ahead market, including Nordic and northern continental Europe. The proposed model considers the procurement of regulating reserves as well as their activation, taking into account available transmission capacity. Different steps of regulating power market integration are studied. The analysis confirms that there is a socioeconomic benefit by integrating regulating power markets. The benefit mainly results from a provision of reserve capacity from the Nordic to the continental European power system, the netting of imbalances and hence the reduced activation of regulating reserves in the continental power system.

13/01854 Assessment of community energy supply systems using energy, exergy and exergoeconomic analysis
Bagdanavicius, A. *et al. Energy*, 2012, 45, (1), 247–255.

Energy, exergy and exergoeconomic analysis are often used for assessing large energy conversion systems. However exergy and exergoeconomic analysis are rarely used when small or medium scale energy generation systems, such as community CHP/CCHP plants or microcogeneration systems are evaluated. In this study energy, exergy and exergoeconomic analysis of four community energy supply (CES) systems has been carried out. Biomass steam turbine CHP (BST), gas turbine CHP (GT), biomass integrated gasification gas turbine CHP (BIGGT) and biomass integrated gasification combined cycle CHP (BIGCC) systems have been modelled. Modelling and energy/exergy analysis have been conducted using the computer program Cycle-Tempo. Exergoeconomic evaluation of CESS has been performed using the specific exergy costing (SPECO) approach. Exergy costs of the main products: heat and electricity, have been calculated. The analysis shows that gasification of biomass reduces overall system efficiency due to the exergy destruction in the thermo-chemical conversion process when air is used as an oxidizer. A GT using natural gas as a fuel and BIGCC are the most exergy efficient systems in this study with the lowest exergy cost of electricity and heat produced. The exergy cost of electricity generated in BST is the highest.

13/01855 Climate protection and China's energy security: win-win or tradeoff

Wu, G. *et al. Applied Energy*, 2012, 97, 157–163.

Since 1996 China became a net importer of crude oil, energy security has faced lots of supply risks and the issues of security on energy using have become more and more acute. The Chinese government has taken a series of policies and measures and enacted relevant laws to guarantee energy security and mitigate global climate change. What changes has energy security in China experienced in these years? What impacts has the implementation of energy security and climate protection policies brought to China's energy security? This paper has established the evaluation indicators and model of the energy security index. The model evaluation results show that: (1) in 1996–2009, the index of China's energy supply security presented an uptrend and then downtrend. For example, it presented a rapid uptrend in 1996–2001, a quick downtrend in 2002–2005, and a slow downtrend in 2006–2009. The energy supply security index in 2009 was kept basically the same as that in 1996. (2) In 1996–2009, the index of China's energy using security presented a fluctuated uptrend. For example, it presented a fluctuating uptrend in 1996–2002, and dropped to a relative low level in 2003–2005, and then quickly rose in 2006–2009. (3) The policy of 'China's energy-saving and emission reduction' has slowed down the decreasing speed of the index of energy supply security and also conspicuously improved the index of energy using security, so that the composite index of China's energy security presented an uptrend, then downtrend and finally uptrend. The policy of 'China's energy-saving and emission reduction' has been successfully conducted, proving that a win-win result can be achieved between climate change protection and China's energy security.

13/01856 Cointegration and causal relationships between energy consumption and output: assessing the evidence from Australia

Shahiduzzaman, M. and Alam, K. *Energy Economics*, 2012, 34, (6), 2182–2188.

This paper describes the investigation of the cointegration and causal relationships between energy consumption and economic output in Australia over a period of five decades. The framework used in this paper is the single-sector aggregate production function, which is the first comprehensive approach used in an Australian study of this type to include energy, capital and labour as separate inputs of production. The empirical evidence points to a cointegration relationship between energy and output and implies that energy is an important variable in the cointegration space, as are conventional inputs capital and labour. The authors also find some evidence of bidirectional causality between gross domestic product (GDP) and energy use. Although the evidence of causality from energy use to GDP was relatively weak when using the thermal aggregate of energy use, once energy consumption was adjusted for energy quality, they found strong evidence of Granger

causality from energy use to GDP in Australia over the investigated period. The results are robust, irrespective of the assumptions of linear trends in the cointegration models, and are applicable for different econometric approaches.

13/01857 Conditional dynamic forecast of electrical energy consumption requirements in Ghana by 2020: a comparison of ARDL and PAM

Adom, P. K. and Bekoe, W. *Energy*, 2012, 44, (1), 367–380.

The frequent power outages which characterizes Ghana's electricity sector have raised serious concerns among policy makers and stakeholders. The causes of this problem have been cited as growing demand and inadequate investment. The objective of this study, therefore, was to identify the factors that affect aggregate electricity demand in Ghana both in the short and long-run as a guide for demand-side management based on two econometric approaches: autoregressive distributed lag (ARDL) and partial adjustment model (PAM). Also predictions of aggregate electricity demand based on these econometric methods were obtained to guide investment decisions in the electricity sector. The result revealed that the positive output, urbanization, and income effects more than offset the negative efficiency effects leading to growth in electricity consumption both in the short- and long-run. The result further establishes the superiority of the ARDL approach to forecasting over the partial adjustment approach to forecasting. For all three scenarios, future domestic consumption levels of electrical energy are predicted to increase *ad infinitum* from 2012 to 2020. Specifically electricity demand is estimated to fall within 20,453 and 34,867 GWh by the year 2020 for all three scenarios. This requires huge capital investments in additional plant capacity.

13/01858 Considering macroeconomic indicators in the food before fuel nexus

Qiu, C. *et al. Energy Economics*, 2012, 34, (6), 2021–2028.

A structural vector autoregression model along with a direct acyclic graph is employed to decompose how supply/demand structural shocks affect food and fuel markets. The results support the hypothesis that fundamental market forces of demand and supply are the main drivers of food price volatility. Increased biofuel production may cause short-run food price increases but not long-run price shifts. Decentralized freely operating markets will mitigate the persistence of any price shocks and restore prices to their long-run trends. The main policy implications are that oil, gasoline, and ethanol market shocks do not spillover into grain prices, which indicates no long-run food before fuel issue. In the short-run, grain prices can spike due to market shocks, so programs designed to blunt these price spikes may be warranted.

13/01859 Developments to an existing city-wide district energy network – part I: identification of potential expansions using heat mapping

Finney, K. N. *et al. Energy Conversion and Management*, 2012, 62, 165–175.

District heating can provide cost-effective and low-carbon energy to local populations, such as space heating in winter and year-round hot/cold water; this is also associated with electricity generation in combined-heat-and-power systems. Although this is currently rare in the UK, many legislative policies, including the renewable heat incentive, aim to increase the amount of energy from such sources; including new installations, as well as extending/upgrading existing distributed energy schemes. Sheffield already has an award-winning district energy network, incorporating city-wide heat distribution. This paper aimed to demonstrate the opportunities for expansions to this through geographical information systems software modelling for an in-depth analysis of the heat demands in the city. 'Heat maps' were produced, locating existing and emerging heat sources and sinks. Heat loads (industrial, commercial, educational, health care, council and leisure facilities/complex) total 53 MW, with existing residential areas accounting for ~1500 MW and new housing developments potentially adding a further 35 MW in the future. A number of current and emerging heat sources were also discovered – potential suppliers of thermal energy to the above-defined heat sinks. From these, six 'heat zones' where an expansion to the existing network could be possible were identified and the infrastructure planned for each development.

13/01860 Developments to an existing city-wide district energy network: part II – analysis of environmental and economic impacts

Finney, K. N. *et al. Energy Conversion and Management*, 2012, 62, 176–184.

District heating can provide cost-effective and low-carbon energy to local populations. Although this is rare in the UK, Sheffield already has an award-winning district energy network. It has been previously determined that this could be expanded to incorporate new heat sources and sinks. This paper determines the environmental and socioeconomic impacts, focusing on various fuels. Combined-heat-and-

power generation in Sheffield coupled with sustainable/renewable fuels, like waste, offer high efficiencies (>77%) and consistently lower carbon emission factors (0.04–0.14 kg/MJ) than conventional energy generation using fossil fuels, since up to 80% of the fuel-carbon is biogenic (CO₂-neutral). Processing municipal waste into a refuse-derived fuel prior to combustion or lowering the return-water temperature by 35 °C in the district heating network could further improve efficiencies (81–93%) and reduce CO₂ emission rates by 4 t/h for the Sheffield plant, increasing avoided emissions from 69,000 to 80,000–91,000 t/a. Moreover, ways in which the energy supply could be further decarbonized were identified, as well as methods to minimize the impacts of responding to changes in demand. Though initial costs of such schemes are high, they can be economically viable for the investor/operator and consequently offer competitive rates for customers. Financial support is also available through government-backed schemes.

13/01861 Efficiency, productivity and environmental policy: a case study of power generation in the EU

Jaraite, J. and Di Maria, C. *Energy Economics*, 2012, 34, (5), 1557–1568.

This study uses the European Union's (EU) public power generating sector as a case study to investigate the environmental efficiency and productivity enhancing performance of the EU's CO₂ Emissions Trading Scheme (EU ETS) in its first phase. Using data envelopment analysis methods, the authors measure the environmental efficiency and the productivity growth registered in public power generation across the EU over the 1996–2007 period. In the second stage of the analysis, the authors attempt to explain changes in productivity and efficiency over time using econometric techniques. The analysis suggests two conclusions: carbon pricing led to an increase in environmental efficiency and to a shift outwards of the technological frontier; and, the overly generous allocation of emission permits had a negative impact on both measures. These results are shown to be robust to changes in controls and specifications.

13/01862 Energy consumption flow and econometric models of two plum cultivars productions in Tehran province of Iran

Tabatabaie, S. M. H. *Energy*, 2012, 44, (1), 211–216.

In this study the amount of energy consumption and its relation with yield in producing two cultivars of plum, Ghatreh Tala and Shablon cultivars, in Tehran province of Iran were studied. For each one of plum cultivars, data were obtained from 100 farmers in the form of personal interview using structured questionnaire method in Tehran province of Iran. Total input energy was found to be 192,652.55 and 168,783.94 MJ ha⁻¹ for Ghatreh Tala and Shablon cultivars production. In Ghatreh Tala and Shablon cultivars production among input energy sources, electricity energy had the highest share with shares of 79.07% and 80.28% of total input energy, respectively. Cobb–Douglas production function was used to determine a relation between input energies and yield in both productions. Results indicated that by using Cobb–Douglas production function to determine mathematical relationship between energy input and yield, human labour energy had the highest impact on yield for both productions. Sensitivity analysis indicated that among the energy inputs human labour energy had the highest MPP value for both plum cultivars productions. The benefit–cost ratios from Ghatreh Tala and Shablon productions were calculated to be 4.18 and 2.46, respectively.

13/01863 Energy efficiency policy in a non-cooperative world

Barla, P. and Proost, S. *Energy Economics*, 2012, 34, (6), 2209–2215. This study explores energy efficiency policies in the presence of a global environmental problem and international cost interdependency associated with R&D activities. The authors develop a simple model with two regions where the cost of an appliance in one region depends upon the level of energy efficiency in that region and the level of R&D activities by the appliance industry. In this model, the cooperative outcome can be decentralized by imposing a tax on energy. However, the authors show that when regions do not cooperate, they have an incentive to adopt additional instruments to increase energy efficiency. The reason is that the lack of cooperation leads to under-taxation of the environmental externality which in turn creates an incentive to try to reduce emissions produced abroad. The authors illustrate this phenomenon with the Californian vehicle greenhouse gas standards.

13/01864 Energy security level assessment technology

Augutis, J. *et al. Applied Energy*, 2012, 97, 143–149.

This paper presents an investigation on the development of energy security level assessment technology. The system of energy security indicators, covering technical, economic and socio-political aspects, is introduced. The security indicator is a special index which gives numerical values to important issues for security of energy sector. In the paper, each indicator is described by presenting the title,

comments, factual and threshold, pre-critical and critical state values. The integral characteristics of these indicators show the level of energy security and in order to identify it, a point system assessment scale is used. The methodology developed in this paper is applied for the assessment of the Lithuanian energy security level in different scenarios. At first, indicator groups are constructed and group weights are determined. The weights of indicators within each group are established in two ways: when all weights are equal and one indicator is dominating. Taking into consideration the assessment of indicators by points, their weights in groups and group weights, the Lithuanian energy security level was determined according to separate indicator blocks. The security level of each indicator and each indicator block, and total security level are presented as the results. The indicators that have the highest impact on the security level increase or decrease are determined as well.

13/01865 Energy, emissions and emergency medical services: policy matters

Brown, L. H. and Blanchard, I. E. *Energy Policy*, 2012, 46, 585–593.

Understanding the energy consumption and emissions associated with health services is important for minimizing their environmental impact and guiding their adaptation to a low-carbon economy. This *post hoc* analysis characterizes the energy burden of North American emergency medical services (EMS) agencies and estimates the potential marginal damage costs arising from their emissions as an example of how and why health services matter in environmental and energy policy, and how and why environmental and energy policy matter to health services. The authors demonstrate EMS systems are energy intensive, and that vehicle fuels represent 80% of their energy burden while electricity and natural gas represent 20%. They also demonstrate that emissions from EMS operations represent only a small fraction of estimated health sector emissions, but for EMS systems in the USA the associated marginal damage costs are likely between \$2.7 million and \$9.7 million annually. Significant changes in the supply or price of energy, including changes that arise from environmental and energy policy initiatives designed to constrain fossil fuel consumption, could potentially affect EMS agencies and other health services. The authors encourage cross disciplinary research to proactively facilitate the health system's adaptation to a low-carbon economy.

13/01866 Exploring the usefulness of a simple linear regression model for understanding price movements of selected recycled materials in the UK

Angus, A. *et al. Resources, Conservation and Recycling*, 2012, 60, 10–19.

The price volatility of recycled materials exposes many different organizations to financial and regulatory risk. These risks can be partially mitigated by improved understanding of price volatility using econometric models, although these have tended to be sophisticated autoregressive models, beyond the analytical capability or cost structure of the average market participant. In this context, this study explores the use of a simple linear regression model to understand the behaviour of prices for recycled plastic, recovered paper and glass, based on the price of their primary inputs, with a specific focus on the UK market. The results of the simple regression model are compared with a wavelet analysis to determine what information is lost in the trade off with simplicity. Both models found significant relationships between the price of crude oil/ethylene/naphtha and recycled plastics and it appears that there is no loss in model performance by using oil as the explanatory variable, rather than direct inputs (ethylene/naphtha). However, few correlations were found for recovered paper and glass. Initial findings from the wavelet analysis suggest that since 2004 the oil price has become more closely linked to the price of recycled plastics. It must be noted that this study is exploratory and particular dynamics of UK markets for recycled materials may affect price development in a way that would not be repeated on international markets.

13/01867 Extended exergy analysis of the economy of Nova Scotia, Canada

Bligh, D. C. and Ugursal, V. I. *Energy*, 2012, 44, (1), 878–890.

Human societies may be modelled as very large complex systems involving multiple flows of energy and materials between different sectors. Traditional exergy analysis methods are inadequate for the analysis of such systems because they do not take non-energetic flows into account. Extended exergy analysis (EEA) allows for the inclusion of exergetic equivalents of non-energetic quantities labour, capital and the costs of environmental remediation. In this work, EEA is conducted to characterize the extraction, conversion, and end use of energy and materials in the economy of Nova Scotia, Canada, in 2006. The economy of Nova Scotia is divided into seven sectors (agriculture, industry, tertiary, domestic, natural resource extraction, energy conversion, and transportation) and each sector is modelled according to its characteristic material and energy fluxes. A model of the structural connectivity of the economy in terms of exchanges between sectors is constructed. Equivalent values of exergy are computed for each flow of energy and material, and energy, exergy and extended

exergy efficiencies are calculated for each sector of the economy of Nova Scotia and compared with those of Norway, China, Italy, Netherlands and the UK.

13/01868 Fuelwood consumption patterns in Chumriey Mountain, Kampong Chhnang Province, Cambodia

San, V. *et al. Energy*, 2012, 44, (1), 335–346.

The study was carried out to explore fuelwood consumption rate for different activities, such as cooking, boiling water, preparing animal feed and burning to protect cattle against insects; species preference; and to examine the characteristics of cook stoves. Approximately 96% of sampled households depend on fuelwood as a primary source for cooking, boiling water, preparing animal feed and protecting cattle against insects. Average fuelwood consumption for cooking and boiling water in very large families is significantly higher than that with very small families. Overall average fuelwood consumption for cooking and boiling water per family per day is 5.21 ± 0.11 and 2.82 ± 0.11 kg. Households with a high number of cattle or pigs consume a higher amount of fuelwood for producing smoke to protect cattle against insects or preparing pig feed. The average fuelwood consumption rate is approximately 5.60 ± 0.11 kg day⁻¹ family⁻¹ for repelling insects to protect animals and 3.90 ± 0.19 kg day⁻¹ family⁻¹ for preparing pig feed. The most preferred species is *Shorea obtusa* followed by *Dipterocarpus obtusifolius*, *Xylia xylocarpa*, *Cratogeomys prunifolium* and *D. tuberculatus*. Two models of improved cooking stoves (the New Lao stove and the Kong Rey stove) are the most frequently used stove type in the study area.

13/01869 Identifying the fuels and energy conversion technologies necessary to meet European passenger car emissions legislation to 2020

Bishop, J. D. K. *et al. Fuel*, 2012, 99, 88–105.

The focus of European emissions legislation for light goods vehicles centres on tank-to-wheel (TTW) operation, despite the importance of the well-to-tank (WTT) impacts of supplying transport fuels. This work presents defensible calculations of best estimate and best-in-class WTT pathways to supply conventional and non-conventional fuels. These estimates are weighted by the availability of resources. The best estimate pathway is the peak of the distribution of WTT estimates obtained from the literature. The best-in-class pathway has the lowest greenhouse gas (GHG) emissions per unit of fuel delivered and represents the state of the art. These fuel pathways are paired with energy conversion (vehicle) technologies and compared with equivalent well-to-wheel (WTW) targets for 2015 and 2020. Of the 103 best estimate fuel-vehicle combinations, 42 meet the 2015 emissions legislation. By 2020, only 17 combinations meet the more strict emissions limit. Petrol production will require net negative GHG emissions, even if blended with bioethanol, to meet the equivalent WTW 2020 target. For the three main combustion energy-conversion technologies, a median efficiency improvement of 29% is required when paired with the best estimate fuel pathways. However, using best-in-class pathways indicates that all of the energy conversion technologies can meet the revised 2015 target, but some still fail to meet the 2020 target. Improvements in TTW technologies alone will not meet the legislative targets, and many fuel-vehicle combinations cannot deliver an overall reduction in GHG emissions.

13/01870 Impacts of removing fossil fuel subsidies on China: how large and how to mitigate?

Lin, B. and Li, A. *Energy*, 2012, 44, (1), 741–749.

The Group of Twenty industrialized nations (G20) committed to removing inefficient fossil fuel subsidies at the 2009 Pittsburgh Summit. China is a large energy consumer with large subsidies. Then, how large are impacts of subsidy removal, and how to mitigate negative impacts? This paper simulates the potential impacts of subsidy removal, and compares different policy options to mitigate the adverse effects. The main findings are as follows. First, subsidy removal would affect the competitiveness, output, welfare and emissions of different world regions disproportionately. Second, subsidy removal in China would result in competitiveness issue through trade channel, which would generate negative externalities to China, but positive externalities to other world regions without subsidy removal. Third, subsidy removal in China would result in rebound effects, which would generate positive externalities to regions without subsidy removal, but be harmful to world's emission reductions. Looking ahead, the government should develop a well-designed planning to overcome resistances to subsidy removal.

13/01871 Inter-technology knowledge spillovers for energy technologies

Nemet, G. F. *Energy Economics*, 2012, 34, (5), 1259–1270.

Both anecdotal evidence and the innovation literature indicate that important advances in energy technology have made use of knowledge originating in other technological areas. This study uses the set of US patents granted from 1976 to 2006 to assess the role of knowledge

acquired from outside each energy patent's technological classification. It identifies the effect of external knowledge on the forward citation frequency of energy patents. The results support the claim above. Regression coefficients on citations to external prior art are positive and significant. Further, the effect of external citations is significantly larger than that of other types of citations. Conversely, citations to prior art that is technologically near have a negative effect on forward citation frequency. These results are robust across several alternative specifications and definitions of whether each flow of knowledge is external. Important energy patents have drawn heavily from external prior art categorized as chemical, electronics, and electrical; they cite very little prior art from computers, communications, and medical inventions.

13/01872 Is added sustainability equal to added value?

Rodrigues, L. *et al. Energy Conversion and Management*, 2012, 63, 203–207.

Almost half of the UK's carbon emissions come from the use of buildings and houses alone account for more than 30% of all primary energy demand. In an attempt to reduce this impact, the British government is pushing towards the development of energy efficient and zero-carbon buildings, both in new construction and in the existing stock. But how is the market receiving such buildings? Are energy-efficient buildings gaining a competitive advantage in the current marketplace? In some countries such as The Netherlands, energy efficient houses reach values 2.8% higher on average than normal houses. In the UK the sustainability property index reveals that, for the properties examined in 2010, regular properties delivered a cumulative total return of –10.8%, compared with –14.9% for more energy efficient ones. This is bad news considering the higher capital investment usually needed to achieve zero-carbon buildings. The current reality in the UK market seems to be that people may not (yet) be willing to pay more rent for energy-efficient buildings. As rent and capital value are inexorably linked, whether or not a building is zero carbon does not yet seem to be affecting property value. This paper does not present definitive answers but discusses possible reasons for that through two case studies and their positions in the marketplace, and suggests that the situation may change as energy prices increase and buildings acquire a potential 'earning capacity' through the use of renewable energy technologies and feed-in tariffs. The introduction of Energy Performance Certificates has also started to impact on the market. Could energy efficient buildings become a property sector in their own right in the near future, with premium priced accordingly? Or is simply that we do not yet have an ability to identify from the data whether the market is differentiating?.

13/01873 Market power in emissions trading: strategically manipulating permit price through fringe firms

Tanaka, M. and Chen, Y. *Applied Energy*, 2012, 96, 203–211.

Tradable emission permits have received considerable attention recently. One emerging issue is its interaction with electricity markets, specifically, market power in the permit markets. One challenge in studying market power in the permit markets is that the demand for permits is implicitly determined by the system conditions. Traditional ways of modelling market power (e.g. standard Cournot model) cannot directly apply. This paper develops a model in which Cournot firms in the market can manipulate the permit price through fringe firms. There are two central findings in this paper. First, diverting emission permits from Cournot to fringe producers always reduce the power and the permit prices, which could improve social surplus. Second, when the fringe producer's emission rate is low, diverting permits from the 'dirty' (i.e. more-polluting) Cournot producer to the 'clean' (i.e. less-polluting) Cournot producer leads to a decline of both power and permit prices. Therefore, the initial allocation of the emission permits could be a useful regulatory tool to mitigate the abuse of market power. The authors also illustrate these results through a numerical simulation of the California electricity market.

13/01874 Optimization of Korean energy planning for sustainability considering uncertainties in learning rates and external factors

Kim, S. *et al. Energy*, 2012, 44, (1), 126–134.

During the past few decades, energy planning has focused on meeting domestic demand at lower total costs. However, global warming and the shared recognition of it have transformed the problem of energy planning into a more complex task with a greater number of issues to be considered. Since the key issue is to reduce greenhouse effects, governments around the world have begun to make investments in renewable energy systems (e.g. hydro, wind, solar and/or biomass power). The relatively high costs of renewable energy systems and the uncertain outlook of their rate of diffusion in the market make it difficult to heavily rely on them. The uncertain variations in production cost over time are especially challenging. To handle uncertainties, the concept of the learning rate was adopted in this study so as to compute the costs of energy systems in the future and Monte Carlo simulation

was performed. The aim of this study was to optimize plans of conventional and prospective renewable energy systems with respect to production cost. The production cost included capital, fixed, variable, and external costs. For the case study, the energy situation in South Korea was used. The results of the case study where the proposed methodology was applied could provide useful insights economically and strategies of sustainable energy management for ambiguous environments.

13/01875 Population density and efficiency in energy consumption: an empirical analysis of service establishments

Morikawa, M. *Energy Economics*, 2012, 34, (5), 1617–1622.

This study, using novel establishment-level microdata from energy consumption statistics, empirically analyses the effect of urban density on energy intensity in the service sector. According to the analysis, the efficiency of energy consumption in service establishments is higher for densely populated cities. Quantitatively, after controlling for differences among industries, energy efficiency increases by approximately 12% when the density in a municipality population doubles. This result suggests that, given a structural transformation toward the service economy, deregulation of excessive restrictions hindering urban agglomeration, and investment in infrastructure in city centres would contribute to environmentally friendly economic growth.

13/01876 Potential impacts of emission concerned policies on power system operation with renewable energy sources

Pal Verma, Y. and Kumar, A. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 520–529.

The electricity sector is considered as a major source of greenhouse gas emissions. A huge opportunity exists within this sector to cut down the emissions and make a significant contribution to mitigate climate change. The emission trading schemes and inception of renewable energy sources into the generation mix contribute to the reduction of emissions and impact electricity market operations. This paper investigates the impact of emission-related policies, such as: (a) fixed emission quotas; (b) cap and trade; and (c) bilateral contract commitments; on the operation of power system. The renewable support mechanisms, such as renewable purchase obligation and feed-in-tariff are incorporated so as to account for the relative costs of cleaner and renewable generation technologies. Each generator is allocated certain emission allowances which they can use to cover emissions during energy generation. The electricity and emission prices are obtained from the interaction of carbon and energy markets. It is observed that the renewable support mechanisms affect the generating and emission trading schedules of independent power producers. They help them meet their emission targets and increase overall welfare. A balance between the emissions regulation and renewable support mechanisms is essential otherwise they make each other's effects redundant. The performance of the proposed model is demonstrated by its implementation on a five-generator system.

13/01877 Projection of U.S. forest sector carbon sequestration under U.S. and global timber market and wood energy consumption scenarios, 2010–2060

Nepal, P. et al. *Biomass and Bioenergy*, 2012, 45, 251–264.

This study provides a modelling framework to examine change over time in the USA's forest sector carbon inventory (in US timberland tree biomass and harvested wood products) for alternative projections of US and global timber markets, including wood energy consumption, based on established IPCC/RPA scenarios. Results indicated that the US forest sector's projected capacities for carbon sequestration could be notably altered by use of forest resources for energy. A scenario with large expansion in US wood energy consumption (16-fold increase by 2060) coupled with high global growth in gross domestic product would convert US timberlands to a substantial carbon emission source by 2050, as timber growing stock inventories would be depleted because of increased biomass energy production. In contrast, the same high growth in the economy coupled with much smaller expansion of US wood biomass energy consumption (less than two-fold increase by 2060) would result in a projected increase in average annual additions to US forest sector carbon by up to four-fold by 2060. Results also indicated that higher cumulative carbon emissions from increased use of wood for energy could be partially offset – over time – by increased forest plantations and more intensive forest management that could be stimulated by the increased use of wood for energy. The modelling framework will enable future use of the USFPM/GFPM market modelling system to evaluate the impacts of forest carbon offset policies on forest carbon and forest products markets, by allowing carbon offset payments to compete in the model with forest products or wood energy for the control and use of available timber resources.

13/01878 Regional integration of renewable energy systems in Ireland – the role of hybrid energy systems for small communities

Goodbody, C. et al. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 713–720.

Due to a lack of indigenous fossil energy resources, Ireland's energy supply constantly teeters on the brink of political, geopolitical and geographical unease. The potential risk to the security of the energy supply combined with the contribution of anthropogenic greenhouse gas emissions to climate change gives a clear indication of Ireland's need to reduce dependency on imported fossil fuels as primary energy source. A feasibility analysis to investigate the available renewable energy options was conducted using HOMER software. The net present cost, the cost of energy, and the CO₂ emissions of each potential energy combination were considered in determining the most suitable renewable and non-renewable hybrid energy system. Wind energy was shown to have the greatest potential for renewable energy generation in Ireland: wind energy was a component of the majority of the optimal hybrid systems both in stand-alone and grid-connected systems. In 2010 the contribution of wind energy to gross electricity consumption in Ireland approximated 10%, and the results of this feasibility study indicate that there is great potential for wind-generated energy production in Ireland. Due to the inherent variability of wind energy the grid-connected system results are particularly relevant, which show that in more than half of the analyses investigating electrical energy demand the incorporation of wind energy offset the CO₂ emissions of the non-renewable elements to such a degree that the whole system had negative CO₂ emissions, which has serious implications for Kyoto Protocol emissions limits. Ireland also has significant potential for hydropower generation despite only accounting for 2% of the gross electricity consumption in 2010. Wind and hydro energy should therefore be thoroughly explored to secure an indigenous primary energy source in Ireland.

13/01879 Renewable energy issues and implementation of European energy policy: the missing generation?

Michalena, E. and Hills, J. M. *Energy Policy*, 2012, 45, 201–216.

The European Commission has set renewable energy (RE) targets at the member state level, however, at the local scale there are many issues related to renewable energy implementation. In this work, a meta-analysis of European RE generation issues from international scientific literature was carried out. Fifty-four local RE implementation issues were identified. Five main clusters of issues were determined, some were aligned along sectoral lines (e.g. governance and technology) but others were inherently multi-sectoral (e.g. complexity and multiplicity of factors), challenging the traditional sectoral view. Results show that RE issues are not just a finite list of independent issues but are hierarchical, multi-scale and cross-linked. As a further step, these issues clusters were linked to the European RE policy and subsidiarity through the National Renewable Energy Action Plans (NREAP) in selected member states. European Union (EU) policy and NREAP subsidiarity proved limited in their scope in dealing with local RE issues. With this scope, the way that EU policy partially fails to facilitate delivery of RE targets, promotes weak subsidiarity through NREAPs and does not address local issues of RE, is discussed.

13/01880 Renewable energy perspectives in the frame of Turkey's and the EU's energy policies

Şekericioğlu, S. and Yilmaz, M. *Energy Conversion and Management*, 2012, 63, 233–238.

Renewable energy as one of the current and substantial issue needs to be investigated in terms of political outlook. So the researches on renewable energy policies under the energy policies of different countries are necessary. The emergence of renewable energy policy was the twentieth century but it gained momentum in twenty-first century. The realization of the polluting nature of the petroleum products, their negative environment effects and the assumptions about the future of non-renewable energy sources were the driving forces behind these policies. The European Union (EU) in these conditions tries to play pioneer role. Turkey on the other hand as a candidate country has to harmonize its policies with the EU's. In this context, objective of this work is to examine the EU and Turkey's renewable energy policies, make a comparison and as a sustainability of Turkish renewable energy policy construct a future projection in short, medium and long terms.

13/01881 The changing demand for energy in rich and poor countries over 25 years

Seale Jr., J. L. and Solano, A. A. *Energy Economics*, 2012, 34, (6), 1834–1844.

Country-specific income and own-price elasticities of demand for private consumption of energy are compared across time and affluence for 43 countries that participated in the 1980, 1996, and 2005 international comparison program (ICP) based on estimates from a 10-good-demand system. Results indicate that income elasticities of

demand for energy are significantly larger than unitary in 1980, are approximately unitary in 1996 but become inelastic for all 43 countries in 2005. Own-price elasticities decrease absolutely going from 1980 to 1996 to 2005 ranging from -0.8 to -1.0 in 1980, -0.7 to -0.8 in 1996, and -0.6 to -0.7 in 2005. Elasticity estimates are also calculated for the set of countries in 1996 and 2005 that do not participate in the ICP in 1980.

13/01882 The effort to bring existing buildings towards the A class: a discussion on the application of calculation methodologies

Magrini, A. *et al. Applied Energy*, 2012, 97, 438–450.

The diffusion of the energy certification in Italy is gradually making the users aware of the buildings' energy performance, at least in some regions. For the existing buildings, the challenge is not only the energy performance calculation, but the analysis of the refurbishment strategies to obtain low energy buildings towards the A class. Basing on European Standards EN ISO 13790 and EN 15316, the Technical Standards UNI/TS 11300 (parts 1 and 2) represent the procedures defined at national level. They allow different approaches and levels of simplification in the calculation of various representative energy parameters that could bring to variations in the results. The first aim of the work is the analysis of the most suitable solutions for existing buildings and the real possibilities to move towards the A-class requirements. Another considered aspect is the application of different calculation methods to reach this target, showing how different choices in terms of input data and methodologies (allowed by the Technical Standards) can bring to different values of the energy performance indices. This could represent a problem for the reproducibility of the calculations and their reliability in the definition of the class level reachable through refurbishment. The research has been supported by the analysis of some representative cases of common national residential building stock, comparing the energy performance obtained with different calculation methods allowed by National Technical Standards and laws. The results show some differences that can lead to ambiguities about the class definition and the most suitable methodology to adopt. Some considerations to obtain reliable values of energy performance addressing the refurbishment towards the A class are presented.

13/01883 The impact of energy performance certificates: a survey of German home owners

Amecke, H. *Energy Policy*, 2012, 46, 4–14.

The building sector accounts for about 40% of the final energy consumption in Germany. At the same time, the sector is regarded as one of the most cost-effective options for saving CO₂ emissions. To target this potential, the European Union (EU) introduced energy performance certificates (EPC). EPCs should provide clear information about the energy performance of buildings to building purchasers, owners and tenants. This study analyses, in how far EPCs have helped purchasers of owner-occupied dwellings in Germany to incorporate energy efficiency in their purchasing decisions. The results suggest that the effectiveness of EPCs is limited. Main reasons are first, that the certificates are not helpful for understanding the financial implications of energy efficiency. Second, EPCs are not viewed for most buildings due to their legal status. Third, energy efficiency is only a minor purchasing criterion for dwelling purchases. The results of the study however also point to the potential of EPCs, as these barriers can be removed. From 2013 onwards the use of the EPC will be increased due to the new EU Energy Performance of Buildings Directive (EPBD). Changes to the design of the EPC could further increase the importance of energy performance certificates and of energy efficiency.

13/01884 The meaning of energy systems for the genesis of the concept of sustainable development

Schlör, H. *et al. Applied Energy*, 2012, 97, 192–200.

The paper describes the genesis of the idea, the term and the concept of sustainable development. The driving forces of sustainable development were fundamental crises, which were essentially crises of the energy system. The idea originated during the energy crisis of the medieval agrarian solar energy system in the fourteenth century. The term originated when the agrarian solar energy system could no longer satisfy the growing energy demands of the emerging industrial age and reached its ecological boundaries at the end of the eighteenth century. The concept originated at the end of twentieth century, when the fossil energy system reached its ecological limits and society was in search of a concept reconciling ecological, economic, and social goals for present and future generations. Currently, we are witnessing a slow transition to a new, probably post-fossil, energy age. All experience from history shows that we have reason to assume that the as yet visionary new solar energy system will also face new problems and limitations. Managing the present and future in a sustainable way is a task that will

accompany humanity on its way into the future and will therefore necessitate the further development of the concept of sustainable development.

13/01885 The reality and statistical distribution of energy consumption in office buildings in China

Xiao, H. *et al. Energy and Buildings*, 2012, 50, 259–265.

This paper analysed the energy consumption of office buildings in several provinces and municipalities directly under the control of the central government of China, utilizing data from the first national survey of about 4600 samples which was conducted in 2007. The electricity use intensity excluding district heating (EUI excl. DH) of different cities or provinces was analysed. By conducting a cluster analysis, it was found that a unique 'dual sector distribution' feature exists in office buildings in China, compared to a 'single-peak distribution' characteristic in Japan and the USA. The research also intended to explain the possible reasons behind this phenomenon. The Lorenz curve and Gini coefficient methods were used as references in order to reveal the regional disparity in China. The results suggested that: (1) EUI excl. DH of office buildings in each city or province in China appeared two different groups, most of them distributed on the lower range from 33.6 to 77.5 kWh_e/(m² a), excluding district heating energy use, while some of buildings fell within a higher range from 51.8 to 107.0 kWh_e/(m² a). (2) The Gini coefficient illustrated that the more developed of urbanization, the less significant of distribution difference, and the higher the EUI excl. DH of office building in China.

13/01886 The risks of an energy efficiency policy for buildings based solely on the consumption evaluation of final energy

dos Santos, A. H. C. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 70–77.

Energy efficiency policies for buildings have the principal objective of reducing the energy consumption required for maintaining activities, as well as ensuring that services are being provided at appropriate levels of quality. Analysis of the different international standards and regulations has shown that there is no universal concept of energy efficiency, and the technical approaches of each policy can be classified into two categories: simplified or expanded. Extended approaches may be either exergetic or qualitative. Simplified regulations are restricted to evaluating the transformation of final energy into useful energy, while expanded regulations also consider the consumption of primary energy. A simplified analysis of energy efficiency is a useful tool for assessing the energy performance of a building and the processes and equipment it uses. However, this tool is not sufficient for evaluating the resource consumption and environmental impacts arising from energy use or in making comparisons between buildings and processes that use different energy sources. Countries such as the USA and European Union members have extended exergetic regulations for the evaluation of energy efficiency in buildings; Brazil and India have qualitative regulations, whereas China and Russia have simplified regulations. Limitations were identified in the qualitative and simplified regulations, such as the difficulty of identifying which technological routes actually lead to lower primary energy consumption and which energy sources can preferably be adopted for certain end uses, such as heating water. When evaluating the efficiency of the electricity generation sectors in Brazil, China, India and Russia, it was found that the final energy quality is related to its origin and that this quality can vary significantly in certain time periods. This reinforces the importance of considering this parameter in the efficiency assessment policies. It should be emphasized that the evaluation of primary energy consumption should not only serve as a point for decision making, but also as a support for broader evaluations of different technologies and energy sources. It is also important to consider other parameters in the evaluation of end uses, such as the peak electricity demand, variations of daily load curves, the supply seasonality of certain forms of energy, dependence on imports and investments required to maintain the supply/purchase of more efficient systems.

Energy conservation

13/01887 A decision support model for reducing electric energy consumption in elementary school facilities

Hong, T. *et al. Applied Energy*, 2012, 95, 253–266.

The South Korean government has been actively promoting an educational-facility improvement programme as part of its energy-saving efforts. This research seeks to develop a decision support model for selecting the facility expected to be effective in generating energy savings and making the facility improvement program more effective. In this research, project characteristics and electric-energy consumption data for the year 2009 were collected from 6282 elementary

schools located in seven metropolitan cities in South Korea. In this research, the following were carried out: (i) a group of educational facilities was established based on electric-energy consumption, using a decision tree; (ii) a number of similar projects were retrieved from the same group of facilities, using case-based reasoning; and (iii) the accuracy of prediction was improved, using the combination of genetic algorithms, the artificial neural network, and multiple regression analysis. The results of this research can be useful for the following purposes: (i) preliminary research on the systematic and continuous management of educational facilities' electric-energy consumption; (ii) basic research on electric-energy consumption prediction based on the project characteristics; and (iii) practical research for selecting an optimum facility that can more effectively apply an educational-facility improvement program as a decision support model.

13/01888 Assessment of potential energy saving using cluster analysis: a case study of lighting systems in buildings

Petcharat, S. *et al.* *Energy and Buildings*, 2012, 52, 145–152.
The promulgation of a building energy code needs an accurate estimation of potential energy savings to ensure that its implementation can achieve the goal set. Generally, the estimation is carried out using the mean value averaged from sample buildings as a representative for the whole sector. However, the actual data of building energy performance may not be described by a single normal distribution. In this study, cluster analysis is thus introduced to estimate potential energy savings in lighting systems in buildings, in comparison with the general averaging approach. The study covers analyses of both simulated and actual data. The simulated data of lighting power density (LPD) is generated from Gaussian distributions for 36 cases with different means, variances, and mixing proportions for the investigation. For actual data analysis, LPD values of commercial buildings are extracted from an energy audit database. It is found that the clustering technique yields more accurate energy saving estimation of the actual values (0–11% error) than that computed by the general approach (1–100% error). The proposed clustering method can therefore be used to estimate the potential energy savings for lighting systems in buildings with high accuracy.

13/01889 Considerations on design optimization criteria for windows providing low energy consumption and high visual comfort

Ochoa, C. E. *et al.* *Applied Energy*, 2012, 95, 238–245.
Apparent window size contradictions arise when optimizing simultaneously for low energy (small sizes) and visual comfort (large sizes). Diverse multi-objective optimization methods exist, but basic questions must be solved beforehand such as choosing appropriate evaluation measures. This work aims to determine the suitability of combined optimization criteria on window sizing procedures for low energy consumption with high visual comfort and performance. The paper showcases diverse measures available to valorize energy consumption and visual aspects. A series of energy and visual criteria were selected, defining acceptance thresholds for dynamic evaluations. Whole-building computer simulations were performed on a standardized office located in a temperate climate. Discrete window-to-wall ratio variations were studied to demonstrate how these criteria affect the solution space. Results were classified using a graphical optimization method, obtaining a solution space satisfying both energy and visual requirements. Most project expectations can be met within the range of sizes. However, unprotected windows barely meet acceptance criteria, needing additional control devices. Applying various related criteria with adequate values increases the diversity of acceptable solutions but too many limits it. Clear objectives and acceptance ranges have to be conceptualized in order to translate them into decisions. This becomes important when involving team design.

13/01890 Design strategy for maximizing the energy-efficiency of a localized floor-heating system using a thermal manikin with human thermoregulatory control

Foda, E. and Sirén, K. *Energy and Buildings*, 2012, 51, 111–121.
Localized heating, ventilation and air-conditioning systems with the task-ambient conditioning concept represent a promising option towards energy-saving in buildings. The design of such systems needs to involve evaluation of the local thermal comfort that corresponds to different body segments. In this work, an experimental technique using a thermal manikin was developed to determine the optimum configuration(s) among different variants of localized floor-heating systems for a single seated person. The experimented variants had different geometries or surface areas. Their surface temperatures were experimentally found subject to thermal comfort criteria and under a lowered ambient temperature. In the experiments, the thermal manikin was regulated in a dynamic mode using a model of human thermoregulation and was employed to evaluate the fulfilment of the thermal comfort criteria. The experimental setup was constructed to simulate a

task area in a large hall space that may be feasible for shopping mall's application. The energy consumption of the floor-heating systems was measured to evaluate the energy performance of the different system variants. The results showed that in large hall space under lowered ambient temperature around 18 °C, a heated floor with certain geometries and a surface area of nearly 1 m² could fulfil the comfort criteria and represented the optimum configuration.

13/01891 Dilemma between economic development and energy conservation: energy rebound effect in China

Lin, B. *et al.* *Energy*, 2012, 45, (1), 867–873.
Promoting technological development to improve energy efficiency has been the primary method of energy conservation in China. However, the existence of energy rebound effect will impose negative effects on the final result of energy saving. This paper adopts the Malmquist index approach to estimate the contribution of technological progress to economic growth. It also uses the logarithmic mean weight divisia index to measure the impact of technological improvement on the energy intensity. Based on the above, the authors set up a model to estimate the technology-based energy rebound effect in China. The results show that, over 1981–2009, energy rebound effect amounts averagely to 53.2%, implying that China cannot simply rely on technical means to reduce energy consumption and emission. Economic instruments should also be applied as supplements to ensure results of energy conservation and emission reduction.

13/01892 Economic feasibility of a novel energy efficient middle vessel batch distillation to reduce energy use

Babu, G. U. B. *et al.* *Energy*, 2012, 45, (1), 626–633.
It has long been recognized that the highly irreversible operation of batch distillation involves more wastage of energy compared to continuous flow distillation. For boosting its energy efficiency, the middle vessel batch distillation (MVBD) column has been invented. In this paper, a rigorous model for an MVBD process for the separation of a ternary hydrocarbon system is developed to simulate its transient behaviour. In order to obtain the products at their maximum achievable purities, the authors devise the two operating policies for the representative configuration. This contribution introduces a heat pumping system in the MVBD aiming to further improve its energetic and economic potentials. This novel heat integration technique is operated with a variable speed compressor for pressurizing the overhead vapour before thermally coupling it with the reboiler liquid. Interestingly, along with the compression ratio (CR), the other two manipulated variables are the inflow rate of overhead vapour to the compressor and that of an external medium (here, steam) that provides make-up heat to the reboiler. The operation of this adaptive heat pump assisted column originally involves the simultaneous adaptation of two variables throughout the entire batch processing. The simulation results show that a cost savings predicted in the heat integrated MVBD scheme can be achieved along with a substantial reduction in energy consumption.

13/01893 Energy savings potential in buildings and overcoming market barriers in member states of the European Union

Tuominen, P. *et al.* *Energy and Buildings*, 2012, 51, 48–55.
In this study the barriers to energy savings and the policy measures set up to overcome these barriers were mapped by interviewing stakeholders in 10 European Union (EU) member states. In addition, an estimate of energy savings potential was calculated. It seems that in most countries cost-effective energy savings of about 10% can be achieved by 2020 and 20% by 2030. A total annual energy saving of approximately 150 TWh by 2020 and approximately 280 TWh by 2030 appears possible. This can be compared to the total annual primary energy consumption of 21,000 TWh in all EU countries combined. Barriers and policies to overcome them were also studied. This was based on a literature review, stakeholder interviews and in-depth homeowner interviews in 10 member states. A commonly cited problem was that people are not keen to improve energy efficiency of their homes as it does not proportionately increase the value of the property. Another widespread problem was that energy prices do not include all the negative external costs that the use of energy causes, such as pollution. The most commonly reported public policy measures in use related to information dissemination and subsidies for energy efficiency retrofits.

13/01894 Energy substitutability and modernization of energy-consuming technologies

Hritonenko, N. and Yatsenko, Y. *Energy Economics*, 2012, 34, (5), 1548–1556.
The paper examines long-term strategies of capital modernization under different assumptions about embodied technological change, energy regulation, and substitutability between energy and capital. To describe modernization of physical capital, the authors use a vintage capital model with the constant elasticity of substitution between

capital and energy. The models take into account (i) availability of new more energy-efficient equipment under energy-saving technical progress, (ii) possibility of buying new capital with various combinations of energy parameters and prices, (iii) controlled scrapping of obsolete capital, and (iv) energy regulation quotas. The paper analyses how the elasticity of substitution between capital and energy impacts the capital modernization policy. In particular, it is proven that the optimal lifetime of capital appears to be longer for a larger elasticity.

13/01895 Evaluating target speeds of passenger trains in China for energy saving in the effect of different formation scales and traction capacities

Feng, X. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 42, (1), 621–626.

Based on computer-aided simulations of passenger transports by different kinds of trains in China, this research analyses the changes of traction energy costs of these trains taking different formation scales and traction capacities with the improvements of their target speeds from the technical viewpoint of train traction calculation. It is found that the increase of the traction energy cost (TEC) of a high-speed railway (HSR) train is as over twice fast as the improvement of its target speed. In contrast, the increase percentage of the TEC of a metro train is only about one-fourth of the improvement ratio of its target speed. Moreover, long formations of HSR trains increase their TECs due to the speed restriction by switches of tracks. Furthermore, expanding the formation scale of a metro or conventional locomotive hauled passenger train by adding trailers decreases its TEC with paying more transport time because of its decreased accelerating ability, which requires the ratio of its trailers to be determined for its traction energy saving under the prerequisite of a necessary transport efficiency of especially a busy rail line.

13/01896 Microgrids: planning of fuel energy management by strategic deployment of CHP-based DERs – an evolutionary algorithm approach

Basu, A. K. *International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 326–336.

Planning of fuel energy management of a CHP-based microgrid requires strategic deployment of distributed energy resources (DERs). Strategic deployment of DERs is meant to select their optimal locations, optimal sizes and optimal technologies. Optimal locations and sizes, which are independent of types of CHP-based DERs used, are selected, here, by loss sensitivity index (LSI) and by loss minimization using differential evolution (DE) algorithm respectively. In the context of planning of a 14-bus radial microgrid present paper incorporates originality in ideas in the analysis technique based on differential evolution (DE) algorithm to evaluate how different optimal output sets of a group of four DERs, while operating within their respective capacity limits as well as tracking an electrical demand without grid participation, could satisfy a range of heat demands, each representing a specific solution of optimal fuel consumption. For investment decision in the perspective of the owner of the microgrid, the author performs the analysis with two separate groups of 4-DER each of various sizes – one group with all diesel generators and other with mix of diesel generators and microturbines. As the present microgrid is intended to cater both heat and electric demands, as per profiles, to its all-commercial customers, a boiler is considered as need-based back-up source to meet the deficit of daily heat generation, if any, for balancing the daily heat demand. At the best result of optimal fuel cost of each group obtained from above analysis, an economic comparison is done between the two groups with the help of payback period, internal rate of return and net present value of the microgrid to decide better investment option of the two. The results of DE are confirmed and then compared with the particle swarm optimization technique.

13/01897 Modeling international trends in energy efficiency

Stern, D. I. *Energy Economics*, 2012, 34, (6), 2200–2208.

In this study, the author uses a stochastic production frontier to model energy efficiency trends in 85 countries over a 37-year period. Differences in energy efficiency across countries are modelled as a stochastic function of explanatory variables and the authors estimate the model using the cross-section of time-averaged data, so that no structure is imposed on technological change over time. Energy efficiency is measured using a new energy distance function approach. The country using the least energy per unit output, given its mix of outputs and inputs, defines the global production frontier. A country's relative energy efficiency is given by its distance from the frontier – the ratio of its actual energy use to the minimum required energy use, *ceteris paribus*. Energy efficiency is higher in countries with, *inter alia*, higher total factor productivity, undervalued currencies, and smaller fossil fuel reserves and it converges over time across countries. Globally, technological change was the most important factor counteracting the energy-use and carbon-emissions increasing effects of economic growth.

13/01898 Modern development of an adaptive non-intrusive appliance load monitoring system in electricity energy conservation

Tsai, M.-S. and Lin, Y.-H. *Applied Energy*, 2012, 96, 55–73.

Traditionally, electricity energy consumption of a residence can be monitored through the watt-hour meter installed at the panel. However, the power consumption of individual appliances cannot be identified directly. To track and control the energy consumption of each appliance, many meters are needed. This approach results in high financial costs. To reduce the installation costs, the non-intrusive appliance load monitoring (NIALM) approach was proposed recently. In this paper, a novel adaptive non-intrusive appliance load monitoring (ANIALM) system that integrates appliance energizing and de-energizing transient feature extraction methods with soft-computing techniques is developed to keep track of the energy consumption of each appliance. The energizing and de-energizing transient responses of appliances can be captured through the analyses of ANIALM. Two recognizers, *k*-nearest neighbour rule (*k*-NNR) and back-propagation artificial neural network (BP-ANN), are used to identify different types of appliances and their operation status under different single-load and multiple-load operation scenarios. The artificial immune algorithm with the Fisher criterion is employed to adaptively adjust the feature parameters in order to improve the identification performance of recognizers when a new type of appliance is added for monitoring. From the experimental results obtained in different actual environments, the proposed ANIALM system is confirmed that it is able to identify the operation status of appliances. Also, although the generalization of both recognizers is similar and excellent, the *k*-NNR recognizer used by the ANIALM system is preferred from the aspects of recognizers' identification mechanism and training performance due to its simplicity in computation and implementation.

13/01899 Smart metering and systems to support a conscious use of water and electricity

Lima, C. A. F. and Navas, J. R. P. *Energy*, 2012, 45, (1), 528–540.

Brazilian water and electricity utilities demand management tools to allow their customers to analyse, monitor and control their consumption of these services. From a social perspective, efficiency requires the involvement and proactivity of clients who can monitor and audit the actual consumed amounts as well as the values saved as new habits are established. In response to this twofold demand, the proposed system automates remote metering and sub-metering of water and electricity (internal to the residence, installed at interest points) and is integrated into a structured knowledge tool. This integration environment receives the collected electricity and water meter measurements. It provides customers and utility companies with compiled reports containing the historical use, daily and hourly forecasts, and projected savings due to changes in consumption habits and/or use of more efficient equipment. For developing countries with social diversity, such as Brazil, this tool can make a difference in raising awareness by identifying actual consumption. Moreover, this solution adds a new component to the relationship between energy businesses and clients/customers, who can audit and verify their consumption as well as check the reliability of the energy/water service provided.

13/01900 The active-reactive – complete dispatch of an electrical network

Aribia, H. B. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 236–248.

Industrialization and population growth are the main factors that increase electricity consumption. This phenomenon comes with a deep restructuring of the electricity sector. Indeed, new constraints concerning reduction of the gas emissions and the use of renewable sources are imposed. Electrical networks become larger and more complex. The grid operation appears as non-linear problems, multi-objective, having a lot of variables and constraints. Complexity arises from the problem formulation; evolutionary algorithms appear to be problem-solving efficient tools for the resolution. This paper presents three problems, which are related to the electric networks. The economic environmental dispatch problem consists to minimize the fuel cost and the gas emissions. The optimal reactive dispatch consists to minimize the active losses in the transmission lines, the voltage deviations and the cost of compensation devices. Finally the active, reactive and environmental dispatch problem consists to minimize the cost of fuel, gas emissions and the active losses in the transmission lines. To solve these problems an improving strength Pareto evolutionary algorithm method is applied to the New England power system (39 buses, 10 thermal generators). The results demonstrate the ability of the proposed approach to find and maintain a diverse Pareto optimal solution in one single run.

13/01901 The EU CONCERTO project Class 1 – demonstrating cost-effective low-energy buildings – recent results with special focus on comparison of calculated and measured energy performance of Danish buildings

Mørck, O. *et al. Applied Energy*, 2012, 97, 319–326.

In 2007 the Class 1 project commenced. Originally, 442 dwellings were to be designed and constructed as 'low-energy class 1' houses according to requirements set by the municipality of Egedal in Denmark. This means that the energy consumption is 50% below the existing energy regulations. Sixty-five dwellings and about 30 single family houses have been constructed. The Concerto community also includes a kindergarten (completed) and an elderly persons' centre. Currently, because of the financial crisis, only about 200 new dwellings will be constructed. Therefore, a contingency plan (plan B) has been developed replacing some of the new dwellings with renovation projects for public buildings. Simultaneously the originally planned district heating network supplied from a relatively small bio-gasification plant has been substantially enlarged to cover a large part of the existing Stenløse town as well and a large wood-chip heating plant has been added. The project demonstrates the benefits of ultra-low-energy buildings integrated with biomass- and solar heating energy supply. The Class 1 project involves four other countries: Estonia, France, Italy and Romania. These countries develop training activities based on the results and experiences gained from the Danish housing projects. This paper describes the comparisons between measured and calculated energy consumption in a social housing settlement and in a detached single-family house. Results show relatively large discrepancies between measured and calculated results, and discussions on possible explanations are given.

13/01902 The use of building energy certificates to reduce energy consumption in European public buildings

Bull, R. *et al. Energy and Buildings*, 2012, 50, 103–110.

This paper presents evidence for the role of building energy certificates as a behaviour change tool that drives improvements in the energy performance of public buildings. Findings are presented from an evaluation of a large-scale voluntary building labelling campaign, CYBER Display[®]. Energy-Cities, the European association of local authorities, launched its Display[®] campaign in 2001 aimed at encouraging authorities to publicly display the energy and environmental performances of their buildings. Over 500 local and regional authorities in Europe participated in producing over 22,000 certificates. The database contains over 10,000 buildings and provides an excellent opportunity to produce an overview of the broad energy performance trends of buildings in Europe. Common technical factors are identified that lead to improved energy performance. Evidence from a comprehensive survey also reveals a further set of common factors in terms of communication activities that appear to lead to improved energy performance. The paper concludes that while building energy certificates are no panacea for the problem of increased emissions from public buildings, producing and displaying building energy certificates such as the Display[®] poster can act as a catalyst for behaviour change.

13/01903 Using the fuzzy linear regression method to benchmark the energy efficiency of commercial buildings

Chung, W. *Applied Energy*, 2012, 95, 45–49.

Benchmarking systems from a sample of reference buildings need to be developed to conduct benchmarking processes for the energy efficiency of commercial buildings. However, not all benchmarking systems can be adopted by public users (i.e. other non-reference building owners) because of the different methods in developing such systems. An approach for benchmarking the energy efficiency of commercial buildings using statistical regression analysis to normalize other factors, such as management performance, was developed in a previous work. However, the field data given by experts can be regarded as a distribution of possibility. Thus, the previous work may not be adequate to handle such fuzzy input-output data. Consequently, a number of fuzzy structures cannot be fully captured by statistical regression analysis. This present paper proposes the use of fuzzy linear regression analysis to develop a benchmarking process, the resulting model of which can be used by public users. An illustrative example is given as well.

13/01904 Zero energy building in Iran

Vaghefpour, H. and Zabehe, K. *Energy Procedia*, 2012, 18, 652–658.

Photovoltaic and solar ventilation systems are not economical from an investor's point of view and for ordinary people due to the cheap price of fossil energy and electricity. It is possible to conclude that benefiting from photovoltaic modules and solar absorption chillers has more advantages in the field of energy saving, economics and environment for which the primary investment in major level of country has just a return, only within first 5 years. As a result it is proposed that instead of any allocation of subsidies for non-renewable energies, any assistance for manufacturing of these systems may cause a reduction in

environmental pollution and fossil fuel consumption. It has been estimated that growth of electricity consumption rate in Iran is between 6% and 8% for the next 10 years. The relevant costs of construction of new power stations and electricity transferring network is so much high but is possible to be reduced due to the lack of any needs for the transferring network in solar systems. Any promotion in Iran's movement towards sustainable energy has a lot of advantages for the country. World competition of renewable energies will increase through the next years. By providing quick suitable bases for benefiting from solar energy in Iran it is possible to increase the speed of mass production of installations and economic benefits. Any differences of costs for 1 kw/hour of energy out of oil with 1 kw/hour of solar energy will increase in the future from one side and there will be an increase in number of installations and saved energy amount on the other.

17 ENERGY CONVERSION AND RECYCLING

13/01905 An open steam power cycle used for IC engine exhaust gas energy recovery

Fu, J. *et al. Energy*, 2012, 44, (1), 544–554.

In order to improve IC engine energy utilization efficiency, an open steam power cycle used for IC engine exhaust gas energy recovery is proposed. The bottom cycle concept is designed on a four-cylinder naturally aspirated IC engine: with three cylinders taken as ignition cylinder, the last one is used for steam expansion cylinder; IC engine exhaust pipe is coupled with a Rankine steam cycle system which uses the high temperature exhaust gas to generate steam; then, the steam is injected into steam expansion cylinder and expands in the cylinder. In this way, the Otto cycle (or diesel cycle) of traditional IC engine and the steam expansion cycle (open Rankine cycle) are coupled on IC engine. On this basis, the energy recovery potential of this bottom cycle is studied by cycle processes calculation and parameters analysis. The research results show that the recovery efficiency of exhaust gas energy is mainly limited by exhaust gas temperature. The maximum bottom cycle power can reach 19.2 kW and IC engine thermal efficiency can be improved by 6.3% at 6000 rev/min. All those can prove this novel bottom cycle concept has larger potential for energy saving and emission reduction on IC engine.

13/01906 Carbon capture with low energy penalty: supplementary fired natural gas combined cycles

Li, H. *et al. Applied Energy*, 2012, 97, 164–169.

Enhancing CO₂ concentration in exhaust gas has been considered as a potentially effective method to reduce the penalty of electrical efficiency caused by CO₂ chemical absorption in post-combustion carbon capture systems. Supplementary firing is an option that inherently has an increased CO₂ concentration in the exhaust gas, albeit a relatively low electrical efficiency due to its increased mass flow of exhaust gas to treat and large temperature difference in heat recovery steam generator. This paper focuses on the methods that can improve the electrical efficiency of the supplementary fired combined cycles (SFCs) integrated with MEA-based CO₂ capture. Three modifications have been evaluated: (i) integration of exhaust gas reheating, (ii) integration of exhaust gas recirculation, and (iii) integration of supercritical bottoming cycle. It is further showed that combining all three modifications results in a significant increase in electrical efficiency which is raised from 43.3% to 54.1% based on lower heating value (LHV) of natural gas when compared to the original SFC. Compared with a conventional combined cycle with a subcritical bottoming cycle and without CO₂ capture (56.7% of LHV), the efficiency penalty caused by CO₂ capture is only 2.6% of LHV.

13/01907 Characterization of pyrolytic oil obtained from pyrolysis of TDF (tire derived fuel)

Banar, M. *et al. Energy Conversion and Management*, 2012, 62, 22–30.

Due to the increasing emphasis on recycling, related to the two European Commission Directives (End-of-Life Vehicle Directive and the Waste Landfill Directive) affecting the management of waste tyres, there is interest in the development of alternative technologies for recycling waste tyres. One use for them is pyrolysis. For this purpose, a fixed bed reactor was used to pyrolysis of tyre-derived fuel at the temperatures of 350, 400, 450, 500, 550 and 600 °C with the heating rates of 5 and 35 °C/min. The maximum pyrolytic oil yield (38.8 wt%) was obtained at 400 °C with 5 °C/min heating rate. The yield of pyrolytic oil decreased with increasing pyrolysis temperatures whereas the yield of gases increased. The fuel properties of the pyrolytic oil including higher heating value, elemental composition, flash point, viscosity, distillation and density were determined. Pyrolytic oil was characterized by Fourier transform infrared spectroscopy, hydrogen

nuclear magnetic resonance spectroscopy and gas chromatography–mass spectroscopy techniques and also, the amount of polychlorinated dibenzodioxins/polychlorinated dibenzofurans and congener distribution characteristics were studied for determination of environmental effects. It was seen that the pyrolytic oils have similar fuel properties with the diesel. It was also found that pyrolytic oil contained 0.00118 I-toxic equivalent quantities/g at very low level. Finally, the pyrolytic oil can be evaluated for energy recovery according to regulation on control of waste oils in Turkey.

13/01908 Discussion of the effects of recirculating exhaust air on performance and efficiency of a typical microturbine

De Paepe, W. *et al. Energy*, 2012, 45, (1), 456–463.

This paper reports on a specific phenomenon, noticed during steam injection experiments on a microturbine. During the considered experiments, measurements indicated an unsteady inlet air temperature of the compressor, resulting in unstable operation of the microturbine. Non-continuous exhaust air recirculation was a possible explanation for the observed behaviour of the microturbine. The aim of this paper is to investigate and demonstrate the effects of exhaust recirculation on a microgasturbine. Depending on wind direction, exhaust air re-entered the engine, resulting in changing inlet conditions which affects the operating regime of the microturbine. For this paper, a series of experiments were performed in the wind tunnel. These series of experiments allowed investigation of the effect of the wind direction on flue gases flow. Next to the experiments, steady-state simulations of exhaust recirculation were performed in order to study the effect of exhaust recirculation on thermodynamic performance of the microturbine. Dynamic simulations of the non-continuous recirculation revealed the effects of frequency and amplitude on average performance and stability. Results from simulations supported the important impact of exhaust recirculation. Wind tunnel tests demonstrated the influence of the wind direction on recirculation and revealed the necessity to heighten the stack, thus preventing exhaust recirculation.

13/01909 District heating in sequential energy supply

Persson, U. and Werner, S. *Applied Energy*, 2012, 95, 123–131.

Increased recovery of excess heat from thermal power generation and industrial processes has great potential to reduce primary energy demands in the European Union's 27 member states (EU27). In this study, current excess heat utilization levels by means of district heat distribution are assessed and expressed by concepts such as recovery efficiency, heat recovery rate, and heat utilization rate. For two chosen excess heat activities, current average EU27 heat recovery levels are compared to currently best member state practices, whereby future potentials of European excess heat recovery and utilization are estimated. The principle of sequential energy supply is elaborated to capture the conceptual idea of excess heat recovery in district heating systems as a structural and organizational energy efficiency measure. The general conditions discussed concerning expansion of heat recovery into district heating systems include infrastructure investments in district heating networks, collaboration agreements, maintained value chains, policy support, world market energy prices, allocation of synergy benefits, and local initiatives. The main conclusion from this study is that a future fourfold increase of current EU27 excess heat utilization by means of district heat distribution to residential and service sectors is conceived as plausible if applying best member state practice. This estimation is higher than the threefold increase with respect to direct feasible distribution costs estimated by the same authors in a previous study. Hence, no direct barriers appear with respect to available heat sources or feasible distribution costs for expansion of district heating within EU27.

13/01910 Effects of flue gas recycle on oxy-coal power generation systems

Hu, Y. *et al. Applied Energy*, 2012, 97, 255–263.

This paper examined and assessed various configuration options about emission removal including particles, SO_x and NO_x in an oxy-coal combustion system for CO_2 capture. A performance analysis was conducted in order to understand the impacts of those options concerning process design, process operation and system efficiency. Results show that different flue gas recycle options have clear effects on the emissivity and absorptivity of radiating gases in boiler due to the change of flue gas compositions. The maximum difference among various options can be up to 15% and 20% for emissivity and absorptivity respectively. As a result, the heat transfer by radiation can vary about 20%. The recycle options also have impacts on the design of air heater and selective-catalytic-reduction preheater. This is due to that the largely varied operating temperatures in different options may result in different required areas of heat exchangers. In addition, the dew point of flue gas and the boiler efficiency are affected by the configurations of flue gas recycle as well.

13/01911 Fly ash recirculation by bottom feeding on a circulating fluidized bed boiler co-burning coal sludge and coal

Duan, L. *et al. Applied Energy*, 2012, 95, 295–299.

Coal sludge is a by-product of coal washing, whose production is huge. Burning it in circulating fluidized bed (CFB) boilers can both recover the heat and reduce the pollution. However, the combustion performances of CFB boilers burning coal sludge are generally not high because the particle size of fuel is small and its resident time in the furnace is short. With the purpose of improving combustion efficiency and reducing pollutions, fly ash recirculation by bottom-feeding (FARBF) technology was applied to a 75 t/h CFB boiler burning mixture of coal sludge and coal. Industrial experiments were carried out to investigate the influence of fly ash recirculation rate on combustion performance and pollutant emission characteristics of the boiler. Results show that with FARBF, the dense bed temperature drops while the furnace exit temperature increases, the temperature distribution in the furnace becomes uniform. Under the condition of 100% maximum continuous rate, the combustion efficiency increases from 92% to 95% and the desulfurization efficiency increases from 83% to 90% as the fly ash recirculation rate increases from 0 to 8 t/h. As the recirculation rate increases, the emissions of NO and CO decrease, but the particulate matter emission increases. The present study indicates that FARBF technology can improve the combustion performance and reduce pollution emissions (except for particulate matter emission) for CFB boilers burning coal sludge, and it can bring significant economic and environmental benefits.

13/01912 Heat integration of regenerative Rankine cycle and process surplus heat through graphical targeting and mathematical modeling technique

Luo, X. *et al. Energy*, 2012, 45, (1), 556–569.

Heat integration, an effective energy-saving technology, has been popularized in many fields. In the current paper, pinch-based heat integration technology is applied in the heat integration of process surplus heat (PSH) and regenerative Rankine cycle (RRC)-based steam power plant. PSH is recovered by preheating boiler feed water (BFW) to reduce consumption of steam extracted from the turbine. A systematic hybrid methodology of graphical targeting and mathematical modelling is developed. The objective function is minimal fuel consumption of steam power plant, rather than maximal heat recovery. The terminal temperature and heat load of process-heated BFW are two decision variables. The graphical targeting method is proposed to ascertain the bounds and constraints of the two decision variables. A mathematical model incorporating rigorous simulation of turbine is formulated to achieve the optimal heat integration scheme. Two case studies, one pertaining to the Heat Integration of RRC and PSH at low temperature and the other involving the Heat Integration of RRC and PSH at medium temperature, are elaborated. The results show that significant fuel savings and cold utility reductions are achieved by using the proposed methodology. Compared with other methods of PSH utilization, the proposed heat integration scheme is more feasible and effective.

13/01913 Heat recovery ventilation operation traded off against natural and simple exhaust ventilation in Europe by primary energy factor, carbon dioxide emission, household consumer price and exergy

Laverge, J. and Janssens, A. *Energy and Buildings*, 2012, 50, 315–323. Indoor air pollution has a negative impact on human health, comfort and productivity. Emissions, however, are often related to essential functions of the indoor environment and cannot be eliminated with source control. Ventilation is then used to dilute these pollutants to acceptable concentrations. Due to recent crises in the energy markets and the subsequent quest for higher efficiency in energy use, heat recovery ventilation has gained capstone status in sustainable building concepts. However, along with a reduction of ventilation heat loss, operating a heat recovery unit increases the pressure drop and fan power consumption in the system. These aspects are rarely traded off against each other and even more scarcely for a broad range of operating conditions. This paper addresses this trade-off based on primary energy, carbon dioxide emission, household consumer energy price and exergy frameworks for the different climates in Europe. The results presented here demonstrate that, for the moderate climate region of middle Europe, natural ventilation, simple exhaust mechanical ventilation and heat recovery ventilation have no clear advantage over each other as far as operating energy is concerned. Realistically low specific fan power will make heat recovery ventilation advantageous in virtually all tested conditions.

13/01914 Kirkuk municipal waste to electrical energy

Mustafa, S. S. *et al. International Journal of Electrical Power & Energy Systems*, 2012, 44, (1), 506–513.

Municipal solid waste (MSW) in Kirkuk city in the north of Iraq poses a serious problem having adverse effects on environment and health of the citizens. Both quantity and volume of MSW have continued to increase with the rapid growth of city population. The population of Kirkuk city, on average, has increased by 3% per annum over the past two decades. The population of Kirkuk city is predicted to increase from 1,050,000 in 2008 to 1,445,556 in 2020. The generation of waste is expected to grow in the future with the rise of city population. The daily waste generation is projected to 1000 tonnes in 2011. By 2021, the daily waste will amount to 1200 tonnes. The waste to electricity suggested project in Kirkuk and the choice of electricity generation technology, would lead to improved electricity supply and efficient waste management in the city, and is expected to contribute to technology transfer in this new area. Landfill or biodigester technology seems to be the most preferred technology for Kirkuk city to start with. Potential power for a plant sourcing from the MSW mass to be fed into the national grid was estimated at 5 MW. Equivalent CO₂ emission in the absence of waste to electrical energy project and the emission by proposed project were calculated. The reduction in CO₂ emission is 87.4%.

13/01915 Low-grade waste heat recovery for simultaneous chilled and hot water generation

Garimella, S. *Applied Thermal Engineering*, 2012, 42, 191–198.

An investigation of heat recovery from industrial processes with large exhaust gas flow rates, but at very low temperatures, was conducted. Heat recovered from a gas stream at 120 °C was supplied to an absorption cycle to simultaneously generate chilled water and hot water to be used for space conditioning and/or process heating. With the steep increase in energy costs faced by industry, it may be possible to use previously unviable techniques. At nominal conditions, 2.26 MW of heat recovered from the waste heat stream yields a chilled hydronic fluid stream at 7 °C with a cooling capacity of 1.28 MW. Simultaneously, a second hydronic fluid stream can be heated from 43 to 54 °C for a heating capacity of 3.57 MW. Based on the cost of electricity to generate this cooling without the waste heat recovery system, and the cost of natural gas for heating, savings of \$186/hour of operation may be realized. When extrapolated to annual operation with a 75% capacity factor, savings of up to \$1.2 million can be achieved. The system requires large components to enable heat exchange over very small temperature differences, with the largest component being the waste heat driven desorber. Minor increases in heat source temperature result in substantial reductions in heat exchanger size.

13/01916 Mathematical model of a laboratory-scale plant for slaughterhouse effluents biodigestion for biogas production

Martínez, E. *et al. Applied Energy*, 2012, 95, 210–219.

A mathematical model of a laboratory-scale plant for slaughterhouse effluents biodigestion is proposed. The model reproduces the substrate degradation along with the bacterial population evolution. Data have been recorded from the prototype to adjust the model parameters with a genetic algorithm. These parameters are fitted in a two steps algorithm. The first one adjusts parameters that are directly related to the measured variables [chemical oxygen demand (COD), acetic and propionic acids and methane] with a genetic algorithm, while the remaining ones are fixed to values obtained from the literature. In the second step a gradient descent algorithm is used to carry out a fine readjustment of the whole set of parameters, not only those assumed as fixed but also those fitted with the genetic algorithm. Values of COD, acetic and propionic acids and methane obtained from the simulation of the model with the optimized parameters are very close to those directly obtained from the prototype. As the model efficiently reproduces the behaviour of an anaerobic digester treating slaughterhouse effluents it may be used to test different controllers in order to efficiently obtain both a waste degradation and a methane generation.

13/01917 Modeling and experimental investigation on water-driven steam injector for waste heat recovery

Zhang, Z. *et al. Applied Thermal Engineering*, 2012, 40, 189–197.

This paper discusses a proposed model of the water-driven steam injector that can be used to recover waste heat in many industries. A mathematical model was developed for evaluating the injector recovery performance in this study; the results indicated that a higher inlet steam pressure, lower inlet-driven water temperature or lower inlet-driven water pressure improved the entrainment ratio, whereas the back pressure of the discharge water had little effect on the injector performance. Moreover, a one-dimensional two-fluid analytical model of two-phase flow was presented with a set of closure equations for estimating flow parameters of the whole injector. The one-dimensional model involved a single distinct flow regime, inverted annular flow in the mixing nozzle and throat tube of the injector. The condensation heat transfer and interfacial shear stress were found to be two main factors affecting the static pressure profiles along the injector. A series of experiments were conducted to investigate the performance of the

injector and the pressure distribution along the injector under different operating conditions. The entrainment ratio and flow parameters along the condensing section of the models were reasonably consistent with the experimental data.

13/01918 On-chip two-phase cooling of datacenters: cooling system and energy recovery evaluation

Marcinichen, J. B. *et al. Applied Thermal Engineering*, 2012, 41, 36–51. Cooling of data centres is estimated to have an annual electricity cost of \$1.4 billion in the USA and \$3.6 billion dollars worldwide. Currently, refrigerated air is the most widely used means of cooling data centre's servers, which typically represents 40–45% of the total energy consumed in a data centre. Based on the above issues, thermal designers of data centres and server manufacturers now seem to agree that there is an immediate need to improve the server cooling process. The goal of the present study is to propose and simulate the performance of a novel hybrid two-phase cooling cycle with micro-evaporator elements (multi-microchannel evaporators) for direct cooling of the chips and auxiliary electronics on blade server boards (savings in energy consumption of over 60% are expected). Different working fluids were considered, namely water, HFC134a and a new, more environmentally friendly, refrigerant HFO1234ze. The results so far demonstrated that the pumping power consumption is on the order of five times higher for the water-cooled cycle. Additionally, a case study considering the hybrid cooling cycle applied on a data centre and exploring the application of energy recovered in the condenser on a feedwater heater of a coal power plant was also investigated (modern data centres require the dissipation of 5–15 MW of heat). Aspects such as minimization of energy consumption and CO₂ footprint and maximization of energy recovery (exergetic efficiency) and power plant efficiency are investigated.

13/01919 Parametric and exergetic analysis of waste heat recovery system based on thermoelectric generator and organic rankine cycle utilizing R123

Shu, G. *et al. Energy*, 2012, 45, (1), 806–816.

The paper analyses the combined TEG–ORC (thermoelectric generator and organic Rankine cycle) used in exhaust heat recovery of internal combustion engine theoretically. A theoretical model is proposed to calculate the optimal parameters of the bottoming cycle based on thermodynamic theory when net output power and volumetric expansion ratio are selected as objective functions, which affect system performance and size. The effects of relative TEG flow direction, TEG scale, highest temperature, condensation temperature, evaporator pressure and efficiency of internal heat exchanger (IHE) on system performance are investigated. R123 is chosen among the fluids whose decomposition temperature exceeds 600 K to avoid fluid resolving and resulting in wet stroke when expansion process ends. The thermodynamic irreversibility that occurs in evaporator, turbine, IHE, condenser, pump and TEG is revealed at target working areas. The results indicate a significant increase of system performance when TEG and IHE are combined with ORC bottoming cycle. It is also suggested that TEG–ORC system is suitable to recovering waste heat from engines, because TEG can extend the temperature range of heat source and thereby improve the security and fuel economy of engines.

13/01920 Progress on heat and moisture recovery with membranes: from fundamentals to engineering applications

Zhang, L.-Z. *Energy Conversion and Management*, 2012, 63, 173–195.

Over the past 10 years, much work has been conducted in South China University of Technology on membrane-based heat and moisture recovery. In this review, the progress of these researches is introduced. More specifically, some novel concepts are proposed for heat and moisture transfer analysis. Several novel membranes are designed to accomplish the goal. The results are that a sensible effectiveness of 0.8 and a latent effectiveness of 0.7 are obtained for a total heat exchanger with novel materials and new constructions. When the total heat exchanger is combined with a fresh air refrigeration dehumidification unit, the system COP is improved to 5.8. The membrane systems have been extended to other areas like air humidification, liquid desiccant air dehumidification, and fabrication of selective adsorbents. This review gives a summary of these works and also points out the future research directions. Energy consumption by air conditioning accounts for one-third of the total energy use by the whole society. Cooling and dehumidifying fresh ventilation air constitutes 20–40% of the total energy load for air conditioning in hot and humid regions. Heat and moisture recovery from ventilation air has become a hot topic for building energy conservation in these years. Of the various technologies for heat and moisture recovery, membrane-based total heat exchanger is a promising alternative. Over the past 10 years, much work has been conducted in South China University of Technology for the research on membrane-based heat and moisture recovery, from fundamentals to engineering applications. In this review, the progress of these researches is introduced. More specifically, some novel concepts are proposed for heat and moisture transfer analysis. Several

novel membranes are designed to accomplish the goal. Some novel exchanger structures are constructed and the heat and mass transport phenomena is investigated. Novel prototypes are built for engineering applications. The results are that a sensible effectiveness of 0.8 and a latent effectiveness of 0.7 are obtained for a total heat exchanger with novel materials and new constructions. When the total heat exchanger is combined with a fresh air refrigeration dehumidification unit, the system COP is improved to 5.8. The membrane systems have been extended to other areas like air humidification, liquid desiccant air dehumidification, and fabrication of selective adsorbents. This review gives a summary of these works and also points out the future research directions.

13/01921 Thermodynamic analysis of solar thermochemical CO₂ capture via carbonation/calcination cycle with heat recovery

Matthews, L. and Lipiński, W. *Energy*, 2012, 45, (1), 900–907.
Thermodynamic analysis of an ideal solar-driven cycle for the capture of carbon dioxide using a CaO-based carbonation/calcination cycle is performed for gas mixtures with compositions corresponding to those of atmospheric air and power plant flue gases. Solar energy input requirements are examined as a function of CO₂ molar fraction in the input gas, gas phase heat recovery, solid phase heat recovery, and carbonation and calcination temperatures. Gas phase heat recovery can reduce the solar energy input requirements by 22–99%, with the largest gains occurring at lower CO₂ molar fractions. Solid phase heat recovery can reduce the solar energy input requirements by 0.1–26%, with the largest gains occurring at higher CO₂ molar fractions. For a carbonation temperature of 673 K and a calcination temperature of 1273 K, over 45 MJ per mol of CO₂ captured is required for a CO₂ concentration of 300 ppm with no heat recovery. The minimum solar energy input required with perfect gas and solid heat recovery is 207 kJ per mol of CO₂ captured.

13/01922 Thermoeconomics and industrial symbiosis. Effect of by-product integration in cost assessment

Usón, S. *et al. Energy*, 2012, 45, (1), 43–51.
Industrial symbiosis entails the transformation of linear industrial processes into closed loop systems: matter and energy flows that were wastes become resources for other processes (by-products), resulting in a reduction of both natural resources consumption and waste production. Thermoeconomics has two key advantages as analysis method for industrial symbiosis: it provides a systemic and rigorous framework and, due to the use of exergy for flow quantification, streams of different nature are measured in the same unit. The goal of the paper is to analyse in depth the process of exergy cost formation of flows within a system, which change when it is integrated with other systems, by using two complimentary approaches. First, a strategy based on irreversibility of the different components and effects of waste internalization already developed is applied for the first time to an example of industrial symbiosis. Second, a new method tracing the

origin of the different resources consumed by the system is developed. This approach is very interesting for industrial symbiosis examples, characterized by a diversity of resources. A system composed of a coal-fired power plant, a cement kiln and a gas-fired boiler operating in isolated and integrated fashion is analysed by using both presented approaches.

13/01923 Utilization of CO₂ and biomass char derived from pyrolysis of *Dunaliella salina*: the effects of steam and catalyst on CO and H₂ gas production

Yang, C. *et al. Bioresource Technology*, 2012, 110, 676–681.
Biomass char, by-product of *Dunaliella salina* pyrolysis at a final pyrolysis temperature of 500 °C, was used as feedstock material in this study. The reactions of biomass char with CO₂ were performed in a fixed-bed reactor to evaluate the effect of temperature and steam on the CO₂ conversion, CO yield and gas composition. The CO₂ conversion and CO yield without steam and catalyst reached about 61.84% and 0.99 mol/(mol CO₂) at 800 °C, respectively. Steam and high temperature led to high CO₂ conversion. A new approach for improving H₂ was carried out by using biomass char and Au/Al₂O₃ catalyst, which combined steam gasification of biomass char and water gas shift reaction, and the H₂ concentration was 1.8 times higher than without catalyst. The process not only mitigated CO₂ emission and made use of residual biomass char, but also created renewable source.

13/01924 Waste-to-energy technologies: impact on environment

Tabasová, A. *et al. Energy*, 2012, 44, (1), 146–155.
This paper provides an overview of thermal treatment methods for waste-to-energy (WTE) processes technologies in terms of their performance and environmental impact. It presents the possibilities of waste treatments and related legislation by the European Union (EU). In the Czech Republic there are 19 industrial waste incinerators in wide range of process capacities from 15 kt/y to 0.3 kt/y, and three municipal waste incinerators with nominal capacity 300, 250 and 9 kt/y. Increasing environmental legislation can be considered as a driving force leading to developing novel types of technologies and equipment. It is necessary to reach a balance between economically, technically and environmentally appropriate ways of waste processing provided the emissions limits are respected. Technologies for incineration went through a rapid development from simple waste disposal to current complex WTE units. Up-to-date WTE units have to be designed in such a way to meet the primary purpose of waste treatment first and at the same time to produce as much energy as possible. The advantages of waste thermal processing have been assessed and an attempt for unbiased evaluation made. It can be foreseen that pollution targets set by EU directives are going to be continuously tightened. The development in advanced equipment and tools for improving the WTE technologies is significant. However, a continuous attention and improvement is crucial for obtaining the economical, technical and environmental optimum solutions.